PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF

PHILADELPHIA

VOLUME XXV

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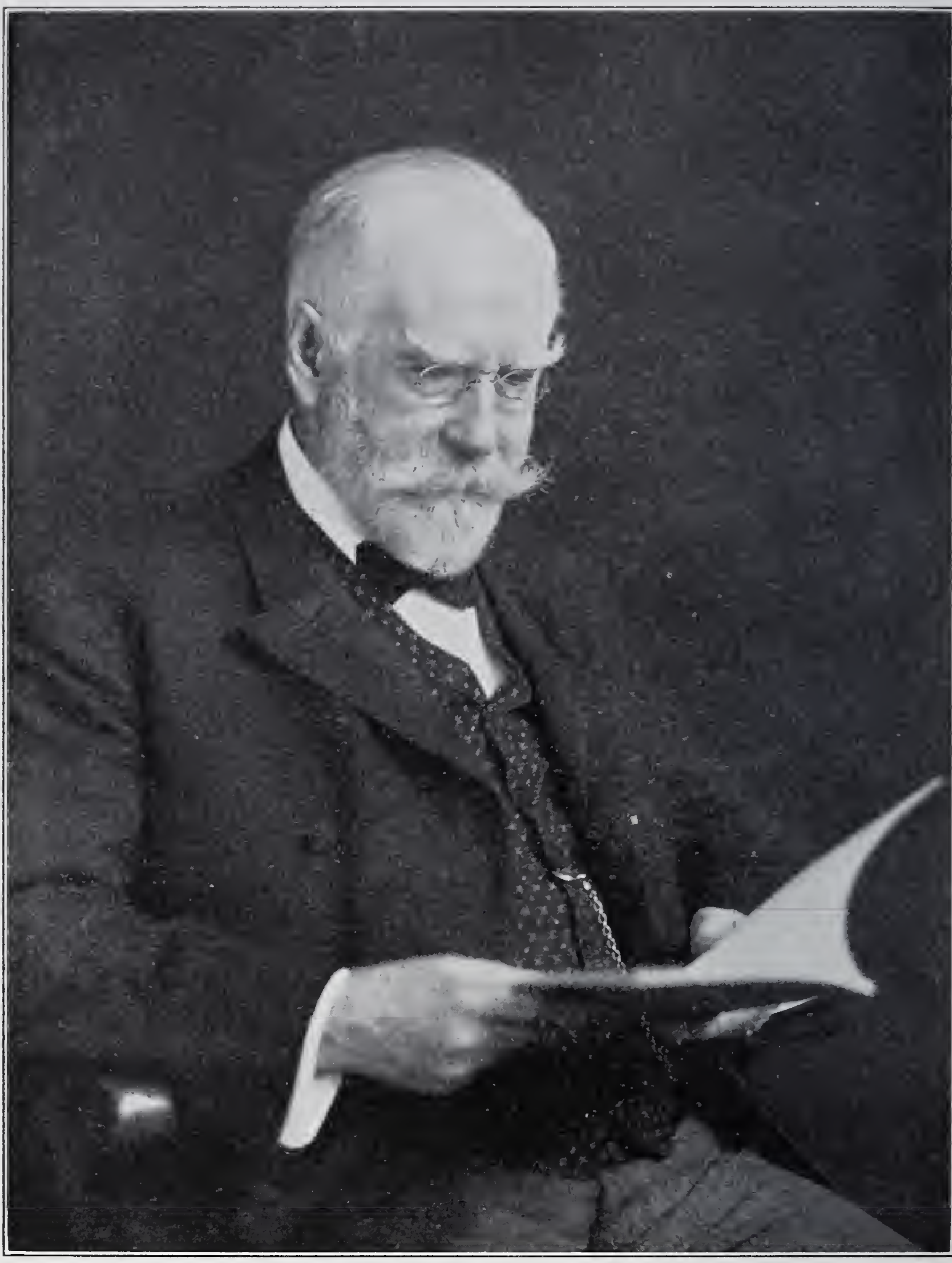

Yours faithfully
Coleman Sellers

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

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PAPER NO. 1048.

THE NECESSITY FOR CORPORATION FORESTRY.

E. A. STERLING.

(Visitor.)

Read December 21, 1907.

THE conservation of natural resources is one of the leading topics of the times, and when a subject becomes current among the thinking and reading public it is reasonably safe to expect results. The American people have been notoriously extravagant of the resources which were made available and valuable as the country developed, and they may expect to suffer in consequence, but it would be unpatriotic to expect failure if they really start out to husband and make the best use of the things which were their inheritance. It takes a long time, and usually the pinch of scarcity, to awaken us to things which are obvious to the academic mind or to our European neighbors, but as an Englishman said the other day, "When the American people do go after anything they get results in five years which it would take Europeans twenty years to achieve." There is, therefore, good reason to hope that ten years hence we will be as active in the conservation of natural resources as we have been in recklessly exploiting them.

Among the resources which we are soon liable to run short of, wood unquestionably comes first, and now that a timber famine is near enough so that men yet in middle age will live to see it, action should

be taken which will perpetuate our timber supply and keep the prices down within reach of the individual and corporation pocketbook.

This end will be achieved by nothing less than the rational practice of forestry, which means, in short, the wise use of our forests and the retention under forest cover of the lands unsuited for agriculture. A decade ago the word forestry was almost an unknown term in America and had no application save as a fad, or as a branch of arboriculture, to which it does not belong. Today the press handles the new-found science side by side with other current topics, and its practice is a business necessity which finds application on extensive national forest areas, maintained as such, and as lumber prices go up and timber becomes more scarce, its economic importance will be increased.

The present agitation is not academic nor theoretical, but is based on an actual need. The credit which is now withheld will be given some day to the men who were at the bottom of the present movement, for such pioneers as Dr. B. E. Fernow, Edward A. Bowers, Dr. John A. Warder, and others gave their time and energy to the work before there was a generally recognized need. During recent years many States and a few individuals and corporations have attempted the practice of forestry or carried on propaganda work. The real movement, however, has had its source in the Federal Government in Washington, where the Division of Forestry of 1898, with 11 men and an appropriation of $28,000, has grown into the Forest Service of 1907, with a force of 1400 men, an appropriation of $3,100,000 and an organization which carries on work in practically every State in the Union. To Gifford Pinchot, National Forester, and head of the Forest Service, is due most of the credit for this remarkable development, which came through his making forestry a business proposition, by managing the national forests in a business way, and by introducing business methods into this branch of a Government department.

At the present time the Forest Service has full control of over 160,000,000 acres of national forests in the West, an area greater than all of New England, New York, Pennsylvania, Maryland, Delaware, and New Jersey combined, worth in the aggregate over a billion dollars, or more than the property value of either the army or the navy. Mr. Pinchot has had a hard fight with the land sharks and timber thieves of the West, but he has won, and there are now very few who deny that his policy of preservation by wise use is right, whereas three years ago there were comparatively few who supported it.

The national forests are primarily for the West, for only beyond the Mississippi was to be found actual or potential forest land which was part of the public domain and could be set aside by presidential proclamation. These forests of the West are open for every legitimate use and even now are contributing in increasing measure to the prosperity of the miner, the stockman, the irrigationist, and the manufacturer. By the policy of wise use the material now mature is being utilized, while by fire protection, scientific cutting, and planting the productiveness of the land is being increased and successive timber crops made possible for the benefit of future generations.

The East shares in these benefits only indirectly, for with all of the forest land in private hands government action is not possible save by direct purchase. This, however, is now being agitated in order to save the remnants of the southern Appalachian forests, and few bills which will be presented at the present session of Congress are more deserving of support than the one providing for the creation of the Southern Appalachian National Forest.

Even with the creation of a national forest in the southern mountains the problem for the East will be only a fraction solved, and the final solution hinges on the disposition and form of management of the private timber lands. The federal holdings comprise not over one-fifth of the forest lands of the country, leaving four-fifths, and this the best, under private ownership. Lumbermen, as a rule, are forced to cut for immediate profit and do not under present conditions see their way clear to log conservatively and hold their land for future crops. The result is that lumbering and fire are rapidly reducing our available timber supply without leaving sufficient young growth to supply future demands.

There are today many indications of timber scarcity which are all too evident to the business man, and it requires only a glance at statistics to show that conditions will rapidly become worse unless prompt action is taken. The rise in lumber prices should in itself be sufficient to point out the need for economy and for the more conservative use of our forest resources, especially when we consider that certain grades of timber are hardly obtainable even now, at any price. Taking our more common kinds of lumber, we find that in the decade ending 1906 the wholesale price per thousand board feet for white pine, rough uppers. jumped from $52 a thousand to $92, while in the same period yellow poplar went from $32 to $53.50 per thousand, southern yellow pine from $14 to $29.50, and hemlock from $12 to $23 per thousand.

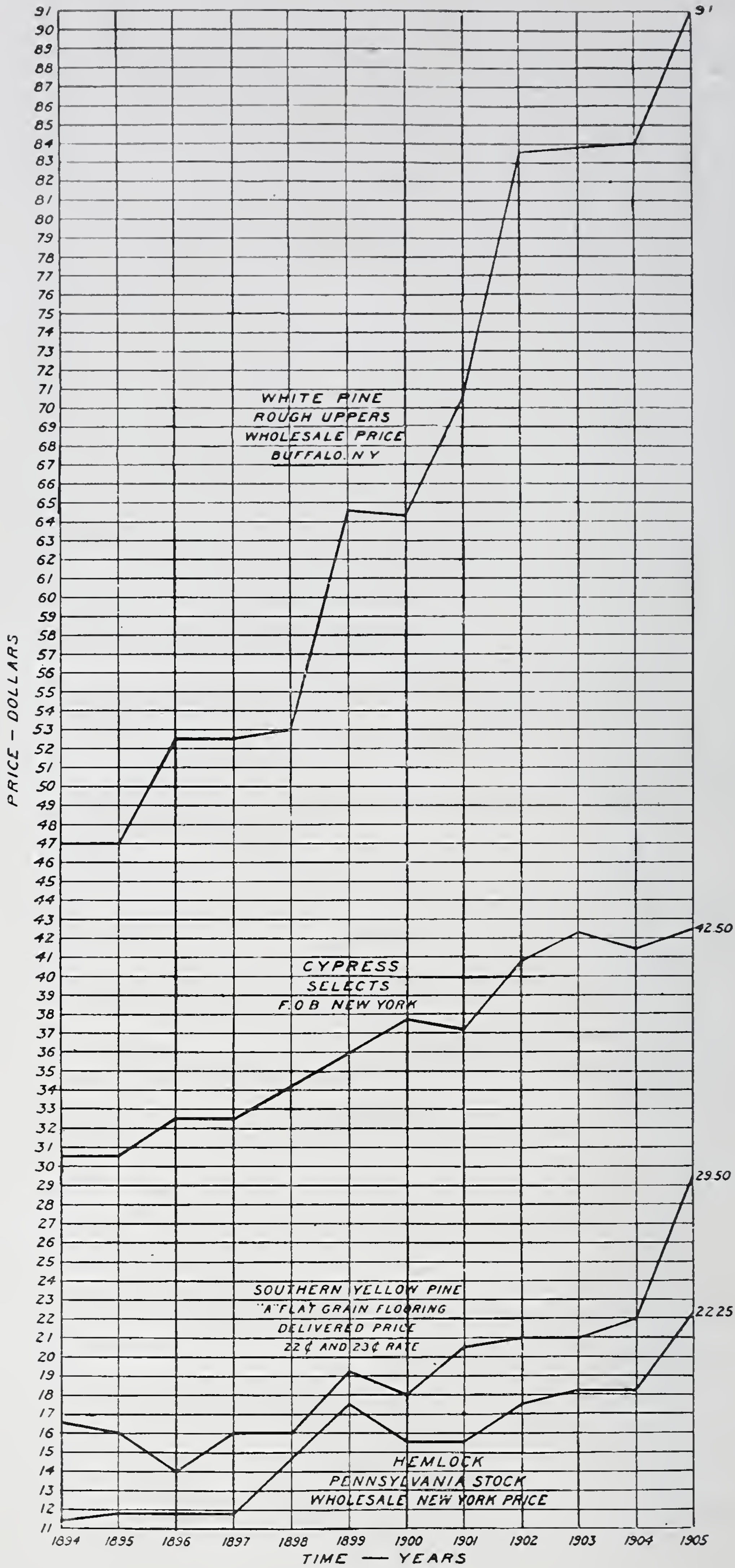

PRICE — DOLLARS
TIME — YEARS
WHITE PINE
ROUGH UPPERS
WHOLESALE PRICE
BUFFALO. N Y
CYPRESS
SELECTS
F.O B NEW YORK
SOUTHERN YELLOW PINE
"A" FLAT GRAIN FLOORING
DELIVERED PRICE
22¢ AND 23¢ RATE
HEMLOCK
PENNSYLVANIA STOCK
WHOLESALE NEW YORK PRICE
91
42.50
29.50
22.25
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905

PLATE I.

Manipulation of the market may have accounted to some slight extent for this marked increase, but it is very certain that the main reason for the advance was the scarcity of the raw material. (See plate I.) Taking white pine, for instance, which has long been one of our standard woods, we find that the total cut in 1905 was only 4,862,000,000 feet, and much of this was obtained by cutting over the original pine lands the second or even the third time. Since the maximum cut of some 8,000,-000,000 feet of white pine back in the eighties there has been a steady falling off despite all efforts of the millmen to maintain higher outputs. The decline in white pine has thrown other woods into the lead, and in 1906 we find that yellow pine and Douglas fir, with 31.1 % and 13.2 %, respectively, have increased rapidly in proportion to the total cut. In 1899, 22.5 % of the lumber cut in the United States was white pine, in 1905 16 %, and in 1906 only 12.2 %, whereas Douglas fir in 1899 produced only 5 % as against the 13.2 % for 1906. Comparing the output of hard woods and soft woods, we find that in 1905, 81.3 % of the total consisted of soft woods such as pine and spruce, whereas in 1899 the soft woods showed about 75 %. This change in ratio is due mainly to the increased cut of yellow pine and Douglas fir and the falling off in oak and yellow poplar.

The situation as regards hickory gives us a very good example of what a certain branch of industry is up against in the matter of timber scarcity. Vehicle manufacturers are obliged to use hickory almost exclusively for the construction of the better grades of vehicles, no suitable substitute having been found, except possibly eucalyptus. The annual consumption of hickory for this purpose is in the neighborhood of 150,000,000 feet, and from the best estimates available the present supply of hickory will not last over twelve years. The question is so serious that the vehicle manufacturers called a special meeting at Niagara Falls one and a half years ago to discuss ways and means of perpetuating the hickory supply, and are now co-operating with the Government to that end.

Another field where the scarcity of certain grades of timber is strongly felt is in railroad work. The supply of white oak, which has been the standard tie timber of the East, has fallen off to such an extent that many inferior species are now used at prices formerly paid for the white oak. Statistics for 1905 show that 44.5 % of all ties used by the railroads of the United States were oak, but it is certain that a large percentage of this oak was classed as red or mixed oak, which gives a service of three to six years less than first-class white oak, with

a corresponding increase in the annual charges. The total annual consumption of cross-ties is reported at 102,834,000, for 1906, of an average value of 47 cents each. It is the experience of practically all of our eastern roads that they must now go farther and farther away from their own lines to get cross-ties of the best quality, the timber tributary to their lines having been cut off in the early days before any thought was given as to where the future supply would come from.

Directly in line with the diminishing supply of white oak ties are recent statistics regarding the waning hard-wood supply throughout the entire East. The hard-wood lumber cut in 1899 was slightly over 8,500,000,000 feet; in 1906 it had fallen to about 7,333,000,000 feet, or a decrease of 15 %. That this decrease was due to a diminished supply rather than to a lessened demand seems unquestionable, since it took place during the period when American industries were developing at an unparalleled rate; when there was the heaviest demand ever known for all classes of structural material; when the output of pig-iron increased 15 %, that of cement 132.17 % and even that of soft-wood timber 15.6 %. During the same period the wholesale price of hard-wood lumber advanced from 25 % to 65 % and substitutes in the form of gum, beech, and other hitherto unused woods were thrown into the market to replace those which could no longer be supplied. Even more striking is the fact that the greatest shrinkage was in the best known and most widely used hard woods. Oak, for instance, which in 1899 furnished over half of the entire output of hard-wood lumber, fell off 36½ %, while yellow poplar declined 37.9 %, and elm, the standard for slack cooperage, went down 50.8 %. Maple, on the other hand, increased 39.4 %, while red gum gained 59 % and advanced from seventh to fourth place. Another startling condition is shown by the marked shrinkage in the production of several of the States which have hitherto furnished most of our hard-wood timber. Ohio with a cut of 918,000,000 feet in 1899 had fallen to 433,000,000 in 1906; Indiana with 976,000,000 feet in 1899 dropped to 446,000,000; while Tennessee's output in the same period dropped from 862,000,000 to 535,000,000 feet.

In view of the certain shrinkage in the output of hard-wood timber the question of how long the supply will last is one which should interest every wood-using corporation. The present hard-wood cut of 7,333,000,000 feet represents probably not over one-third of the hard wood used annually, and 25,000,000,000 feet yearly would not be a high estimate, considering the enormous quantities required for

cross-ties, telephone and telegraph poles, piling, fence posts, etc. In the face of this enormous consumption we have 400,000,000,000 feet as the highest estimate of the standing hard-wood timber. If we are consuming 25,000,000,000 feet a year this will last for only sixteen years, so it is not a matter of the future, but almost of the present as to where our cross-ties and hard-wood lumber will come from.

LUMBER CUT OF UNITED STATES—1880-1906—M.FT.

State	Reported By Census Of				Estimated Total Cut	Per	State
	1880	1890	1900	1905	1880—1906	Cent	
Ala	251,851	586,143	1,096,539	1,243,988	19,625,000	2.8	Ala
Ark	172,503	526,091	1,595,933	1,680,536	23,932,000	3.4	Ark
Calif	304,795	515,823	734,232	1,077,499	15,789,000	2.2	Calif
Colo	63,792	79,906	133,746	141,914	2,614,000	.4	Colo
Conn	64,427	48,277	107,594	69,376	1,874,000	.3	Conn
Fla	247,627	411,436	788,905	812,693	14,802,000	2.0	Fla
Ga	451,788	572,970	1,308,610	1,135,910	21,865,000	3.1	Ga
Idaho	18,204	27,800	65,331	211,447	1,526,000	.2	Idaho
Ill	334,244	218,938	381,584	211,545	7,548,000	1.1	Ill
Ind	915,943	707,115	977,878	563,853	21,165,000	3.0	Ind
Iowa	412,578	568,816	351,769	281,521	11,410,000	1.6	Iowa
Ky	305,684	420,820	765,343	586,371	13,618,000	1.9	Ky
La	133,472	303,591	1,113,423	2,459,327	19,989,000	2.8	La
Me	566,656	564,243	756,515	863,860	17,119,000	2.4	Me
Md	123,336	81,078	183,393	166,469	3,394,000	.5	Md
Mass	205,244	208,655	342,058	262,467	6,637,000	.9	Mass
Mich	4,172,572	4,245,717	3,012,057	2,006,670	93,436,000	13.2	Mich
Minn	563,974	1,079,403	2,341,619	1,942,248	38,174,000	5.4	Minn
Miss	168,747	452,797	1,202,334	1,727,391	20,173,000	2.9	Miss
Mo	399,744	395,755	715,968	553,940	13,346,000	1.9	Mo
Mont	21,420	89,511	255,685	236,430	3,757,000	.5	Mont
N H	292,267	266,890	562,258	491,591	10,103,000	1.4	N H
N J	109,679	32,285	72,660	44,058	1,585,000	.2	N J
N Y	1,184,220	909,990	874,754	581,976	23,765,000	3.4	N Y
N C	241,822	509,436	1,278,399	1,318,411	20,486,000	2.9	N C
Ohio	910,832	541,076	957,239	420,905	18,886,000	2.7	Ohio
Ore	177,171	444,565	734,181	987,107	14,166,000	2.0	Ore
Penn	1,733,844	2,113,267	2,321,284	1,738,972	53,589,000	7.6	Penn
S C	185,772	197,940	466,109	609,769	8,466,000	1.2	S C
Tenn	302,673	450,097	939,463	775,885	15,858,000	2.3	Tenn
Tex	328,968	839,724	1,230,904	1,406,473	24,109,000	3.4	Tex
Vt	322,942	370,155	365,869	337,238	9,255,000	1.3	Vt
Va	315,939	409,804	956,169	949,797	16,176,000	2.3	Va
Wash	160,176	1,061,560	1,428,205	2,485,628	30,299,000	4.3	Wash
W Va	180,112	299,709	773,583	855,889	12,654,000	1.8	W Va
Wis	1,542,021	2,817,200	3,361,943	2,623,157	70,647,000	10.0	Wis
All Others	200,317	126,270	226,977	264,854	4,875,000	.7	All Others
Total	18,087,356	23,494,853	34,780,513	34,127,165	706,712,000	100.0	

PLATE II.

The prospects for the country at large and for the future supply of all kinds of lumber are equally discouraging. According to the most reliable statistics by the Forest Service and Census Bureau we are at present using annually about 40,000,000,000 feet in the form of lumber, 2,000,000,000 feet in the mines, 300,000,000 feet for tight cooperage,

600,000,000 feet for packing boxes in New England alone, 700,000 cords in distillation plants, and over 3,000,000 cords for pulp wood and a large quantity for fuel and other purposes; in other words, our total

PLATE III.—FINE STAND OF RED SPRUCE AND BALSAM FIR KILLED BY FIRE; HUMUS BURNED OUT ONE FOOT DEEP; GREEN FOREST IN BACKGROUND. PICEA RUBENS, ABIES BALSAMEA. LYON MT., NEW YORK.

consumption of timber cannot be far from 50,000,000,000 board feet per annum, worth in the aggregate over a billion dollars. If we include fuel wood, and take the lowest estimate of 100,000,000 cords,

Plate IV.—Planted Forest of American White Pine near Frankfort-on-Main, Germany.

which is equivalent to 50,000,000,000 board feet, our annual consumption of wood in all forms reaches the staggering total of 100,000,000,000 feet. The United States is now using annually about 440 board feet per capita, while the average for Europe is but 60 feet per capita. (See plate II.)

Despite the increasing use of steel, stone, concrete, and other substitutes for wood, the relative increase in lumber consumption is greater than in population, and our per capita consumption has increased from 360 feet in 1880 to 440 feet in 1906. How long our forests will stand the drain now being made upon them is difficult to estimate, but it is certain that we are rapidly using up our forest capital, and it has been estimated that our present annual consumption of wood in all forms is from three to four times as great as the annual increment of our forests. The most reliable estimates of stumpage in the United States place the amount of standing timber at about 2,000,000,000,000 board feet. This, of course, is only a rough estimate; but the one certain conclusion is that we must adopt less destructive methods of lumbering and control our forest fires, or as a nation we will run short of one of our most indispensable resources before the end of another generation. Assuming a stand of 2000 billion feet, a use of 100 billion feet annually, and neglecting growth, we have twenty years' supply.

The practical men at the head of our industrial enterprises will promptly ask: "What are you going to do about it?" when told that their railroad or their mining company or whatever it may be is going to be without lumber in a comparatively short time. The question in the East will largely have to be answered by themselves, and the solution for most of our large corporations, particularly for the railroads, will be the purchase of large timber tracts, their management on a long-time basis, and preservative treatment of their timber so far as is consistent with the use to which it is to be put. The States will probably accomplish much in the way of forest preservation, the Federal Government will do a great deal more, but nothing short of individual action will assure a definite supply of timber, at reasonable prices, to the larger wood-using concerns. Their demands can properly be filled in the open market for some years to come, provided they are willing to ease up on their specifications and use certain timbers which were formerly thought to be of little value. The time, however, is sure to come when the eastern lumbermen will no longer be able to supply the de-

mands, and, naturally, for some time before this crisis arrives prices of timber will have become practically prohibitive for general uses.

A natural question to ask is why the lumbermen, as the men who own the land and are in the timber business, are not the ones to practise forestry and furnish us with successive crops of timber. Within the last few years a number of lumber tracts have been put under careful management and others are liable to follow the good example set. The fact remains, however, that the lumberman is not in the business permanently nor for his health, and that in most cases he desires to realize promptly on his investment, and to do so must cut

Plate V.—Logging Scene in the White Mountains of New Hampshire.

rapidly, with much apparent waste, and with no provision for a future crop. The large corporations, however, are usually long-lived concerns and will continue to be users of wood long after the lumbermen from whom they are buying today have cut over their lands and gone out of business. This, then, is a fundamental reason why eastern corporations should be the first to go into private forestry on a large scale. By so doing they will not only reduce present operating expenses by handling their own timber tracts, but will be getting their wood at the cost of production ten to twenty years hence when less far-sighted concerns are paying the greatly increased prices which are sure to

obtain at that time. The men who are managers of corporations aim to turn the business over to future managers in better condition than when they took it, and to do this they should give consideration to the question of whence the future wood supplies for their company are to be derived. (See plate V.)

Coming down to concrete cases, we have mining companies in the anthracite coal regions which are spending in the neighborhood of one million dollars a month for mine timbers. This timber is now obtained

Plate VI.—Logging to Small Sizes in the Southern Pineries.

locally or from the South at current prices. One particular company is experimenting on a large scale to determine the most economical method of treating mine timbers with preservatives to increase their life, and the work up to the present time has been very successful. This, however, is but a partial or temporary source of relief, for in ten years they may not be able to procure sufficient timber to supply their treating plants. The chances are that this same company during the past few years could have bought their timber on the stump, with the land thrown in, and exploited it themselves at a cost not in excess of

what they paid in the open market, and by so doing they would have had the second-growth and cut-over land as a source of future supply.

The railroads are pursuing much the same short-sighted policy, and while they are attempting to economize by using inferior timber for ties, and by getting the maximum life out of them, they still hesitate about going to the fountain-head of the matter and making their investment permanent by acquiring the ties on the stump together with the land that produces them. It is safe to say that, if any large eastern railroad company five years ago had invested the cost of five years' supply of ties in timber lands, and had put this land under forest management, it would supply their timber requirements for all time. From the broader national standpoint such action by the corporations would have materially reduced the drain on our dwindling timber supply by insuring the permanent use of large areas for forest production, whereas now these lands are exploited recklessly and rapidly by lumbermen and their value for future crops is in many cases practically destroyed. (See plate VI.)

There are, to be sure, a number of drawbacks and difficulties to a policy of forest management by individual corporations. One of the first would be the task of locating and acquiring title to suitable lands within reasonable distance of the points of consumption. Mining companies, since their operations are usually concentrated within a comparatively small region, would be particularly handicapped, and unless backed by affiliated transportation lines would be obliged to go outside of their own territory and pay the freight charges on material from their timber tracts to their mines. Railroad .companies, on the other hand, with their main lines traversing a wide stretch of territory and feeder lines running back into the more unsettled regions, have a marked advantage. To all will come the realization that they have delayed action too long, because the better and more accessible timber has already been cut off and the prices of the remaining forest lands have enhanced tremendously in the last five or ten years. The better tracts which are in the market today are in most cases inaccessible, which necessitates the expense of building logging railroads in order to exploit them cheaply. Nothing, however, is to be gained by waiting, for the prices still have an upward trend and those who get in first naturally have the best opportunity.

Forest fires have always been the greatest enemy of our American forests and adequate fire protection would be the first step in a corporation forest. On the Pacific coast crown fires in Oregon and Washing-

ton, no later than 1903, destroyed $12,000,000 worth of timber in nine days, and there is one national forest in Idaho where over $100,000,000 worth of timber was burned before the reserve was created and placed under management. In the East, forest fires, while frequent and severe, rarely destroy an entire stand; the damage from the usual ground fires is accumulative and of greater harm to young growth than to mature timber. In any well-managed tract, however, even the ground fires should be suppressed, so that the expense of maintaining a system of fire protection must be incurred from the very beginning. (See plate III.)

Under our system of government the authority given to local county and township officials in the way of tax assessments offers more encouragement to the rapid and wasteful exploitation of timber land than any other one thing, and in most of the States the owners of large timber tracts are forced to pay an annual bounty in taxes which greatly reduces the profits from long-time management of such lands. The people, however, are coming to see, as they have in Europe, that nothing is gained in the long run by high temporary revenues from forest lands, while the ultimate result is the denudation of the mountains, irregular and diminished stream flow, and the temporary instead of permanent existence of lumbering operations which give employment to many thousand men. The rational solution of the problem is a nominal assessment on the land which produces timber, with no tax or assessment on the timber until it is finally cut and marketed. Probably nothing would hasten the enactment of such legislation more than the influence exerted by large corporations if they undertook the practice of forestry on a large scale in States where the matter of forest taxation is now in such an unsatisfactory state. There is, moreover, another saving factor even under present conditions, in that the present increase in the value of timber lands will in most cases pay the taxes and interest on the investment, while giving the timber time to develop and the owner opportunity to exploit it to his best advantage. That it is profitable to acquire and hold large forest areas and that the difficulties are not insurmountable is evidenced by the fortunes made by such men as Frederick Weyerhauser and T. B. Walker, in the West, whose profits have not come from exploiting timber lands for their own use, as would corporations, but by holding them for increased values and by lumbering where conditions made it advisable.

Assuming that a large eastern corporation was in control of a timber reserve, sufficient to fill its wood requirements wholly or in part, the

next question would be how to operate to the best advantage. Naturally, the first step would be to place the property in charge of a forester who would make a plan of management in accordance with the local conditions of the tract and of his company's requirements. On typical forest land his first step would be the inauguration of a scheme of fire protection. This would be followed by such improvements in the line of mills, logging railroads, etc., as were necessary to the exploitation of the timber. With these facilities he could handle the orders placed by his company and deliver the material in any form desired. In cutting, his aim would be to utilize only the mature timber, provide as far as possible for natural reproduction by leaving seed trees and disposing of the slash, and, wherever it could be done with profit or without undue expense, thin out and improve his second-growth timber. He would at the same time replant open areas where there was no prospect for natural regeneration and, in short, would gradually bring every acre of the tract up to its maximum production. The normal forest, with an annual cutting area and an annual budget equal to the increment of the whole stand, he could not expect to approach for many years, but conservative logging methods, fire protection, improvement cuttings, planting, etc., would gradually lead to this end. It is not unreasonable to anticipate that the day will come in this country when our economic conditions will permit the more intensive forest practice of our European neighbors.

There seems to be much misunderstanding as to the place planting should occupy in a scheme of corporation forestry, and the idea that it is the solution of the problem should not be entertained. Forest planting on waste lands, and in conjunction with a plan of intensive management on large forest areas, is an important line of work. However, its cost and the long-time period before returns are available preclude it as a full solution for our corporations' wood problems. In our own work on the Pennsylvania lines east of Pittsburg and Erie over two million trees have been planted on lands acquired in connection with widening and straightening the main line, and in the construction of low-grade lines. The actual cost of plant material and planting last spring was $11.29 per thousand. As an estimate of the returns which may be expected per acre from such work, if red oak is planted on land valued at $10 per acre, with interest at 4½ % compounded annually, and the crop maturing in forty years, we have the following:

Cost of land at $10, at 4½% for forty years,	$58.16
Cost of plant material and planting $10, at 4½% for forty years,	58.16
Taxes 3 cents per annum at 4½% for forty years,	3.21
Management and protection, 15 cents at 4½% for forty years,	16.05
Cost of sawing or hewing 400 ties at 10 cents,	40.00
Cost of hauling 400 ties at 5 cents,	20.00
	$195.58

By the above estimate 400 ties would be produced per acre every forty years at a cost of 48 cents each, including compound interest charges at 4½ %. The market value of such ties forty years hence no one can foretell. The estimate of forty years will hold for red oak and Scotch and red pines; while chestnut should make ties in thirty to thirty-five years and locust in twenty-five to thirty years, if not eaten up by the borers. The trees at the end of this period should average 15 inches on the stump. The tax rate of 3 cents per acre, used above, is far below the present rate, but is what would be considered a fair charge in a European forest. (See plate IV.)

The question as to whether a forest policy will pay must be answered by each individual wood-using corporation on the basis of their own present and future wood requirements. That it does not pay to allow contractors to make a big profit on things they could do equally well themselves, and that it is not economy to be at the mercy of fluctuating and constantly increasing prices for timber, is all too evident. It is equally certain that it is a matter not alone for the present, but that conditions five or ten years hence should be anticipated and the question of profit figured not for 1908 or 1909, but for the long-time period in which the particular corporation will exist.

The optimist says that we probably shall have steel ties by the time wood is gone, that some way of mining without the use of wooden mine props will be found, that our telephone and telegraph wires will be laid underground or that we will be using some wireless system exclusively, that steel cars will take the place of wooden cars, and concrete, stone, and steel will replace wood in buildings. This is all partially true, but there is nothing to indicate that the use of even all of these substitutes will eliminate the necessity for wood. German railroads successfully operate over steel ties, but the fact remains that over 70 % of their total track mileage is still carried on wooden sleepers, and that if wood were obtainable in sufficient quantities and the Government did not require the use of a certain percentage of steel ties in order

to husband the timber, that the percentage of steel ties would be even lower. This can mean nothing less than that German engineers, after years of experience and experimenting, have been unable to design a steel tie which fully meets all requirements. The use of steel for cars, etc., may be expected to reduce the consumption along certain lines, but it is an interesting fact that there has been no appreciable falling off in the use of wood in any industrial enterprise. The increase in population of the United States from 1800 to 1900 was 52 %, while the increase in wood consumption during the same period was 94 %. In ship-building, despite the fact that most of our cargoes are now carried in steel or iron hulls, the total wood consumption in the ship-building industry is greater than in the days of the wooden clipper. There are, then, no present indications that a corporation which acquires a large body of timber land will have a product which will be a drug on the market in a few years.

Although the idea that wood-using corporations should be wood producers as well is comparatively new in this country, several firms have already adopted policies of this kind. Of the eastern railroads, the Pennsylvania and the Delaware and Hudson have appointed foresters and may be expected to work out their wood problems according to their own needs. In the West, the Santa Fe is the most active, and in addition to operating the largest and best creosoting plant in the country at Somerville, Texas, have purchased some 9000 acres of land in southern California, where they will grow eucalyptus for ties. Since eucalyptus in that climate will grow into tie size in eight to ten years, and each tree produce two to three ties, an area of this size when planted will go a long way toward furnishing a continuous supply of tie timber. This same company has over 25,000,000 treated ties in track, and by this one process alone they will probably cut their annual consumption in half. The Southern Pacific, Union Pacific, Burlington, Rock Island, Illinois Central, and other of the large western roads are erecting or operating large wood-treating plants, and within a few years untreated ties will be the exception, west of the Mississippi at least. Of the coal and iron companies, the Lehigh Coal and Navigation Company is practising forestry on a large tract in the Pocono region of Pennsylvania; the Philadelphia and Reading Coal and Iron Company is treating mine timbers; the Lackawanna Railroad, with its affiliated coal interests, is taking up the question of timber production and timber treating, while the Cleveland-Cliff Iron Company in Michigan owns very large areas of forest

lands, which are under the management of trained foresters. Paper and pulp companies in New York and Maine have acquired large holdings of spruce and balsam and are practising primitive forestry, while the International Harvester Company owns and husbands its own supply of hard-wood timber in Missouri.

In conclusion, it can safely be said that most of our large corporations, as a matter of self-protection and economy, must sooner or later take up the practice of forestry. It will pay in most cases because eventually there will be no other solution, and the sooner the start is made the more profitable will be the outcome. From the broader patriotic standpoint of the nation and the State, the corporations and the lumbermen have it in their power to solve the great questions of stream flow, inland navigation, and water power, and to decide whether our lands which are unsuited for agriculture shall be barren wastes or productive of successive crops of timber for the nation's use. From the commercial and economical standpoint the attitude of these same industrial interests will largely determine whether the approaching timber famine shall be postponed indefinitely, or whether we shall soon be made to face a scarcity of one of our most useful products, which will paralyze many of our industries.

DISCUSSION.

A. E. Lehman. (By letter.)—I have just read with deep interest the paper on "The Necessity for Corporation Forestry," by Mr. E. A. Sterling.

The subject of forestry in general is one that my professional work has brought me in close touch with for many years, and as my opportunities for observation have been somewhat ample, I regret not being able to attend the meeting of the Club and take part in the discussion that should naturally follow the presentation of so important a subject.

By having given it some attention on the ground in Europe from time to time, I am able to appreciate how unfortunate we have been in not giving more heed to the experience and examples set us by such countries as England, France, Belgium, Germany, and Switzerland, particularly, to quote the Englishman mentioned in the paper, "When the American people go after anything, they get results in five years which it would take Europeans twenty-five years to achieve." This being the case, if our native conceit was more in inverse proportion to our knack of adaptability, we would be more inclined to profit by the experience of European countries and appreciate the fact that to every hundred years of our existence they have lived a thousand, with experience in proportion. Perhaps something might be learned from them about forestry, as well as a few other tricks in the art of political economy. As between Europe and America, the latter is like a big, strong, overgrown boy, compared to a fully matured,

experienced man. And, characteristic of the boy, in our self-confidence born of inexperience, we fancy we have little to learn from mouldy, slow old Europe.

Would the policy of laws of European countries pertaining to forests and their conservation permit timber to be cut and allow the refuse brush to litter the ground and remain as a menace by fire to the surrounding standing but immatured timber? Would anything but a reckless disregard for the development of a wholesome new growth and true economy permit the refuse material of a timber cutting to go unutilized in any form, or allow it to become a waste and an incumbrance? Is not the practice to be condemned that permits the fallen and dead wood to decay and go to waste as valueless to any one?

Such practices prevailed during our charcoal iron smelting age. In "coaling" operations large areas were entirely denuded of timber, and not even a narrow belt bordering streams was allowed to stand to protect their source. A strip of at least 100 feet on each side should have been left standing for the twofold purpose of shielding the springs and upper waters, and also as a future supply of timber on territory from which the bulk had been taken.

Probably more efficient laws can be established for the proper regulation of our forest property, a system of individual education and missionary work will be required, and a certain reverence cultivated for our forest growth and protection.

It is heart-rending to see on all sides the reckless waste of wood; much of it burned to no purpose, such as packing boxes, barrels, etc. It could be converted into kindling at least. The average American is usually surprised, when observing the building of a fire for domestic purposes in Europe, to see that the finest part of the kindling—the "fagot"—is composed of twigs, the very ends of the tree limbs, saved and neatly bundled as an essential component of the kindling wood.

A man is well known to me who as a child was present at the planting of the seed of an oak, by his father. The acorn has now grown into a noble tree, tall, symmetrical, and about two feet or more in diameter. Few persons have the opportunity to observe as he has the full development of a tree or such other growth. It has been an object-lesson of great value, teaching the period of time necessary for the maturity of a tree to a practical size, belonging to a species of hard wood, of slow development. Such an experience tends also to engender such a reverence and regard for timber as is likely to induce its protection until it attains a size of commerical importance.

Few men not actually in the business of converting our forests into merchantable products have opportunities equal to the active field engineer for observing the mistaken methods that have prevailed. There is no experience or judgment better qualified than that of the intelligent field engineer to criticize the vandalism and devastation perpetrated on the American forest. Many of us have not moved toward measures to prevent further destruction, not because we have not been unmindful of needful effort, but simply for the reason that, like others, we have been dazed by the American passion to convert all our natural resources into "the almighty dollar."

H. H. Quimby.—Mr. Sterling's paper states most impressively some important facts. The figures of growing consumption of wood and diminishing supply ought to be startling. The United States consumption of seven times

as much wood as Europe itself ought to make us think. We seem to be able, however, to take with considerable equanimity the more than startling facts concerning the future. There are always some people who see on ahead; who are far-sighted enough and philanthropic enough to remember to provide for the future, and we have been warned for many years of these facts, but it seems to take a long while to organize the thing into producing results. The paper indicates that results are being produced and that we are learning how to get at them.

J. E. Codman.—In the paper read before the Club this evening, several times mention was made of stream flow, and, inferentially, the effect of deforestation upon the water flowing off of the surface of the ground. It has often been asserted, and is generally believed, that the destruction of the forests that formerly covered the whole country has decreased the quantity of annual rainfall throughout the eastern frontier of the United States. Careful observation and records of rainfall covering a long period of years do not show any increase or decrease from normal conditions; in fact, without great climatic changes from the present conditions and a radical change in the air currents, no decrease or increase in the rainfall from the present yearly average will be found, and deforestation at this time does not affect the resultant run off and stream flow, and this wasteful and almost criminal destruction of our wooded areas is fast changing the condition of our water-supply for either power or sanitary wants. There is no decrease in the amount of water flowing off from the surface of the ground and into the usual drainage channels; in fact, the average stream flow is, if anything, greater from bare cultivated ground areas than from areas of woodland covered either with grown trees or brushwood.

In the past twenty-one years I have had an opportunity to carefully observe these conditions in connection with the hydrographic work carried on by the city of Philadelphia, through the Bureau of Water. Take, for example, the Neshaminy water-shed, comprising about 130.09 miles, on which the bare and cultivated area is 9.4 per cent. of the whole area. This stream is subject to sudden freshet conditions, at any season of the year, followed by very low flows. The fluctuations are extreme; either very high water or very low water.

In heavy rains the water flows rapidly on either the dry, hard ground in summer or the frozen ground of fall, winter, and early spring. Nature's natural protection of the surface of the ground is entirely wanting. There is nothing at present to hold the water falling on the surface from flowing rapidly away into natural channels. There is nothing to hold the snow in winter, and it is blown into valleys and banks, melting rapidly and adding its volume to that of a warm and heavy fall of rain.

These extreme conditions of flow are better realized when it is stated that the maximum flow of this small stream has reached at times 2,482,000,000 gallons in twenty-four hours, or a sufficient quantity to supply the city of Philadelphia at the present rate of consumption for eight days, and the minimum flow is often less than 12,000,000 gallons per day, or not enough to supply the city one hour. The average daily flow of this stream is 151,400,000 gallons per day. This is nearly one-half the present daily consumption.

Where the surface of the ground is covered with tree growth, the snow is held on the surface and the surface water is much retarded in reaching the streams,

but with bare ground the conclusion is evident that large storage basins must be constructed to impound the high flows and carry over the periods of low flow, if the stream is to be utilized for any purposes of power or water supply.

I have selected this stream, for the topography is admirably adapted to illustrate the conditions of a water-shed almost entirely stripped of any tree growth.

I have noticed that in numberless instances the heavy rains of only a few years past have cut channels through fields started by plowing up the surface, three and four feet deep and five to six feet wide, where no such channels existed before. The banks of the stream have been cut out where formerly a few trees stood and the roots protected and held the earth, but, these trees being mostly hickory, ash, and black walnut, the furniture manufacturer is offering a good price for the hickory and ash cut down. The black walnut is sold on the stump, cut down, squared up, and shipped to Europe, no provision being made in any case either to replace the timber growth or protect the banks of the stream.

As a further effect of the bare surface conditions, the month of March of this year presents a very good example. The stream flow for the month of March was 6.06 inches, while the rainfall for the month was only 2.83 inches, or there were 3.13 inches more of water flowing in the stream than rain falling on the water-shed. This condition can be accounted for in this way. During the months of January and February, and the first week in March, the temperature was below the average, and the greater part of the precipitation was in the form of snow on frozen ground. About the tenth of March a remarkably warm spell of weather began, the temperature being much above the average for March and continuing to the end of the month, and recording on one day 86°.

This high temperature melted the snow, and, combined with the average rainfall for the month, flowed over the surface of the still frozen ground and into the natural surface water courses.

No extreme freshet was produced, but a continued high flow was maintained, continuing nearly to the end of the month, resulting in the fact that more than twice the amount of precipitation falling on the ground was found flowing in the stream. Under protected conditions of wooded growth the frost would not have penetrated so deep into the ground, the snow would have melted more gradually, and the ground storage would have received its normal amount for the month of March, whereas the ground storage received little or nothing, as shown by the stream flow for the succeeding month of April, during which the amount flowing in the stream was only 1.56 inches, and the rainfall on the water-shed was 3.50 inches.

Mr. Wilson.—We see published a great deal, and we say a great deal, about the wastage of timber. I would like to ask what that means; whether wastage refers to reckless cutting that destroys other timber; whether an undue proportion is neglected in the woods after trimming the limbs, or whether it is wastefulness in the use of the timber itself; or do these all make up the wastage that we hear so much about? What methods are proposed as fire protection in the forests that are to be planted? What is the best method used? Is it plowed up? We do not always have swampy lands to surround our best timber. Where there is to be a limit made, what is the best plan for effecting such limit?

Then, in the matter of encouragement of those who take up the question of forestry, what important encouragement is there in the matter of taxation so as to make it a nominal tax to those who would undertake replanting forest lands?

Mr. Chambers.—I would like to ask what method is employed in disposing of the slash in locations where it is impossible to give it any market value.

W. F. Ballinger.—As a matter of fact, is not taxation one of the greatest causes for the quick cutting of timber? Is it not uneconomical to grow timber here in the east? For instance: if there is 1 per cent. taxation per annum and it takes forty years for the timber to reproduce itself, it means a taxation of 1 per cent. for forty years, or 40 per cent.; but if that were compounded, I think it would amount to 100 per cent.; that is, to the full value of the timber in forty years, so that where such taxation exists it would not pay anybody to raise timber; therefore the preservation of timber is very largely a political matter.

The United States imposes a duty on all imported timber; if this were removed, Canadian lumber could come in free, which would diminish to some extent the demand for standing timber in this country, and thus help to preserve our water-sheds.

E. M. Nichols.—I would like to ask Mr. Sterling whether small vegetation is advantageous to the growth of the trees. In connection with the individual efforts tending toward the preservation of forests from ravages by fire, I read a while ago, but do not remember in what paper, but it is said that in one instance a gentleman who had some money to spare had bought several tracts of waste land in New Hampshire, where, as we know, there is a great deal of white pine. He practically colonized the place with families of foreigners; gave them the land to work, but told them that just as soon as there was a fire on the place, they would have to get out. The result was a perfect fire protection system, and in fifteen years the land had paid for the investment and 10 per cent. compound interest besides.

Mr. Sterling.—Answering Mr. Wilson's question of waste, it mainly applies to all the points mèntioned. The tree in the woods is only partially utilized, but lumbermen are not all vandals because only part of a tree can be taken out with profit. Prior to a few years, only the logs which made lumber were utilized. The tops could not be taken out and shipped and loaded in with the other material with profit, so there was a waste from one point of view. Recently, however, they have been able to use more and more of these tops, because there is a market for cord-wood, and for bark for tanning and other purposes. We waste millions of feet in packing boxes; you know what becomes of that. They come in with goods and are finally used for kindling, whereas Europeans carefully knock the boxes to pieces and use them again. Architects and builders use scantling for scaffolding, knock it down when they are through, and give the lumber away, or they did so until recently, and it would be impossible to save that lumber. And in a hundred and one ways we have been wasteful in that respect.

As regards fire protection, it is still a great problem. It has to be decided for each individual tract, and is different in the east than in the west. As a usual thing, fire protection is chiefly by prevention, and prevention is accom-

plished by a patrol, by posting warning notices, and by seeing to it that every one understands that fires are not to be permitted, that persons do not throw away lighted cigar stubs in the brush, that hunters are made to put out their campfires, and that other precautions are taken. In the West in the national forests they put in a system of telephone lines; they build trails so that patrolmen can get over the ground rapidly, they build houses for their men here and there, and work the thing differently for each individual tract for the best advantage. In some cases it is found worth while to build expensive fire lines.

The last question about taxation is a big one, and no one as yet has satisfactorily solved it. I believe I told you that it is said that the best plan is to place a nominal assessment on the land, say one dollar per acre, and then tax the timber when it is cut and market it on the basis of the manufactured product—so much per thousand feet. That is the rational way to do, but few of our States have seen fit to go into the question of forest taxation. It is now up in Oregon, but is unsettled. It has been up in Pennsylvania, and for a time we had a rebate, but that has been declared unconstitutional. New York State has not done much for the property-owner, but in the State forests they have placed a nominal assessment on the land, and the State pays taxes to the counties concerned for the roads and schools, but they have not done very much, nor have any of the States settled the question absolutely.

Answering Mr. Chambers' question as to the disposal of slash, the best way depends largely upon the individual tract and on the species. In hard-wood cuttings the opinion is that the best way is to scatter the slash and not attempt to pile and burn it. In the pine lands of Michigan the thing has been worked out best on the Chippewa Indian Reservation, and there it is done by piling and burning during the early spring, but I am not familiar with the method. It costs only about twenty-five cents per thousand feet of lumber. In the Black Hills of South Dakota the slash (the tops and the brush) was piled and burned during the summer season or after a rain when they could control it. The cutting was all done and the brush left in piles to be burned when finished or when convenient. They have tried various methods out in the West; one is throwing it in strips but it is hard to say just what the best method is.

Paper No. 1047.

FOUNDATIONS.

A. B. CLARK.
(Visitor.)

Read December 7, 1907.

I will not attempt to cover the entire field of foundation work, as I do not lay claim to the necessary ability for so doing, and the time available would hardly suffice for any adequate treatment. My purpose is to describe merely some of the less known phases of development on Manhattan Island in the last fifteen years.

The use of isolated piers, extending to bed-rock, for the use of foundations of heavy buildings dates from about 1893, at which time the foundations of the Manhattan Life Building were constructed, by the pneumatic process. Following that work, the demand for unyielding foundations led to the gradual introduction of improvements in the sinking of open pits, in which piers were constructed, rather than by means of pneumatic caissons. A preference for the open method grew out of a desire to economize. Many owners and architects were desirous of securing foundations on bed-rock; at the same time, they realized that the rents to be derived from the buildings would not justify the heavy expenditures required at that time for pneumatic foundations. As a result the open work was favored, and the methods and tools greatly improved. Many thousand piers have been built in pits, the deeper of which exceed fifty feet.

More recently there has been introduced a variety of piles of a permanent type; some of concrete, and some of steel and concrete.

It is my purpose to devote most of my remarks to the use in New York of high capacity piles of steel and concrete. The kind employed, for the most part, consists of sections of heavy tubing joined by interior splices and filled with steel bars and neat Portland cement, or a rich mortar. The tubes vary in diameter from 6 inches to 16 inches, and in thickness from $\frac{1}{3}$ inch to $\frac{1}{2}$ inch. The tubing is received from the

mill with plain ends, faced truly at right angles; the cutting is done after the tube has been placed in position. The tubes now used are almost always of open-hearth, basic steel. The splices are of crucible steel $\frac{1}{16}$ inch thicker than the metal of the tubing. The tubes are sunk to hard bed-rock, and the bars extend from hard bed-rock to the level at which the tube is cut off. The tubing is cut off by a machine which makes a cut similar to that obtained in a lathe. It is usual to drive all the piles composing a group or pier before cutting off any of them. After the sinking machine has been moved alongside of another pier, the piles are cut off, the bars inserted, and the spaces between the same filled with a rich mortar.

The piles now in use range in capacity from 25 to 225 tons each. The load upon bed-rock runs up to as high as 2250 pounds per square inch. The piles, when tested in column length, in the testing machine, show an ultimate resistance of about ten times the load applied to piles of moderate length.

Before advising the use of piles of the form which I have described, I devoted about a year to the investigation of the behavior of iron and steel so buried in the ground as to be inaccessible to air, or, more accurately, I devoted the time to finding out what objects in iron have been removed from such situations, and what conditions they were in when removed. My attention was drawn to the possibility of using something of the sort, through having seen several remarkable—as I then believed—examples of the preservation of metal a long time in the ground.

From the investigation arose the conviction that iron or steel in the ground is preserved indefinitely when not accessible to atmospheric air. Those who have been employed on work below the surface, in the older communities, have no doubt seen pieces of iron that had long lain under ground.

To cite a few instances: the iron pier at Coney Island was constructed of tubes containing only water and running down into the beach, with a disc at the bottom. After being in service a period of twenty-six years, many of them were found to be corroded entirely through at points slightly above the low-water mark. From mud-line down, the tubes were found, upon removal, to be in a state of perfect preservation. A thin coating of light-brown rust covered both the inner and outer surfaces. It could be readily removed with a penknife. Upon drying and weighing, the tubing was found to have lost nothing in weight.

At Lewes, Del., after the piles first put in had been in five years, one of them was removed by United States engineers, for the purpose of inspection. The report is contained in the Report of the Chief of Engineers. The pile was found to be unchanged except above the water-line.

At Mystic, Conn., upon the removal of foundations that had been in a period of thirty-four years, I believe, a quantity of metal in small pieces was found to be in excellent condition. Not a year passes in New York that iron objects which have lain in the ground fifty years or more are not removed, and found to be in a good state of preservation.

The analysis of water, from many parts of the Island, has shown it to be quite impure, and to be strongly impregnated with Glauber's salts. That salt forms a coating upon many pipes found under ground; it also coats the discharge pipes from pumps used by contractors.

As the sinking of the steel tube before referred to differs materially from the sinking of a timber pile, I may be pardoned for devoting a little time to the method of sinking. A pneumatic hammer having a height of about 4 feet is placed upon the top of the first section of tubing. It strikes one hundred and fifty or more blows per minute. The piston of the machine is hollow; through the central shaft thus formed a jet pipe is operated. By applying the jet in this manner the point of application may be shifted in a few seconds. The jet may be applied as low as the end of the tube, or it may be raised 10 feet inside the tube. The stream may, of course, be discontinued or its force increased. The lower end of the jet pipe is equipped with some form of chisel, one being selected which is best adapted to break up the material to be passed through. The first section having been sunk nearly to the level of the ground, the hammer is hoisted by means of a jinniwink, or other light derrick, and the splice put in place and the second section added. The hammer is returned to the top of the pile, the water and air turned on, and the sinking carried on as before. Upon the lower end of the tube reaching bed-rock, the chisel is used freely and portions of the bed-rock removed. In a few instances the tubes have penetrated the soft bed-rock to a depth of 8 feet; they have commonly penetrated 6 to 18 inches. The fragments of rock having been removed, the pile containing only clean water, the reinforcing bars, which are usually round and 2 inches in diameter, are placed, and the water removed from the pile. In cases where quicksand might otherwise enter at the bottom of the tube, the water is displaced by a stream of grout issuing from the bottom of the jet pipe. Owing to the high specific gravity of the

grout, the water flows from the pile, rapidly, through an opening in the sinking machine. Following the removal of the water, concrete is

PNEUMATIC HAMMER IN PLACE ON TUBULAR STEEL PILE.

sometimes deposited, leaving a portion of the grout to overflow and settle about the exterior of the pile.

The bars having been placed in the tube, one or more separators of suitable form are lowered into position, thus spacing the bars, in the

manner desired. The circle on which the reinforcing bars are spaced is as large as will permit a layer of mortar between the bar and the adjacent inner surface of the tube.

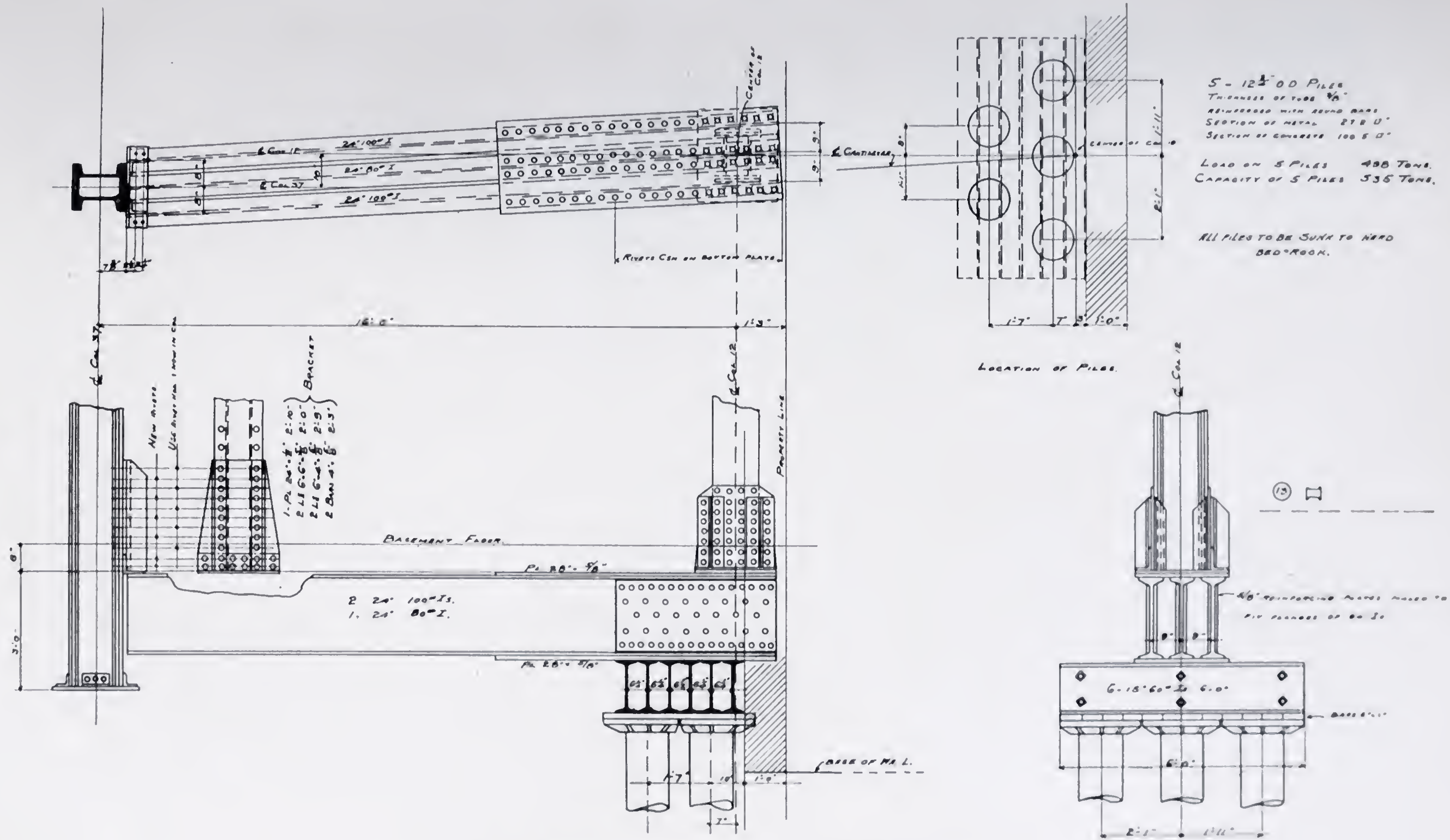
The machines used in sinking and cutting off the tubes are so designed that the latter may be sunk within 3 inches of an adjacent wall. The desirability of such procedure arises from the saving effected by the elimination of cantilever girders, except in certain situations where there are party walls. Such girders are almost invariably done away with and, in a large percentage of cases, the shoring of adjacent walls is also eliminated. By means of the sinking outfit which I have described, the tubes can be sunk without cracking, or in any way endangering the adjacent walls. The tube very seldom gets out of the position indicated on the plan, because, being straight, and properly started in the ground, it proceeds under impulses which act only along lines parallel with its axis. Thus it is entirely practicable to so arrange the piles with reference to a wall column that each and every one will have the same load. The elimination of the cantilever girder not only saves the cost of the steel; it also saves excavating several feet deeper and, oftentimes, obviates the necessity for shoring the adjacent walls, because the additional excavating is done away with.

The cutting off is accomplished by a small machine which is lowered over the tube and clamped to it, after which air is turned into the air motor which drives it; by means of high-speed tool steel, the tubes are cut off in less time than would be required in a machine shop.

The tubes having been filled flush, with bars and rich mortar, the pile is covered with a cast-iron cap similar to an inverted column base, and the adjoining caps united by means of a block of reinforced concrete, which embraces the heads of the piles and forms a platform on which the grillages are placed, as in the case of other forms of piers.

In cases where the saving of vertical distance will result in an economy, owing to the elimination of shoring, the grillage beams are placed directly upon the caps covering the piles, the latter being cut off accurately at a uniform height.

In the case of long piles, the bars are coupled together by means of a short round coupling having conical ends which fit the drill holes in the ends of the bars. A cross-pin $\frac{3}{8}$ inch or $\frac{1}{2}$ inch in diameter suffices to hold the weight of the bar until it can be placed in proper position within the tube; when the strain upon it is released, the several sections come to a bearing. The top section of reinforcing bar is usually cut a little short and shims are used, at the top, to bring all the bars to the level of the top of the tube.



Pile Pier Located against a Party Wall.

The discharge opening in the sinking machine, through which emerges silt, water, and other materials, is not large enough to pass the boulders which are sometimes encountered. Recently a 45-pound boulder was taken out of a 12-inch tube. The larger boulders remain in the tube until the tube reaches rock, or until they hinder sinking to a considerable degree. Then the hammer is removed, the wash-pipe connected with an air receiver, and the entire charge of air turned suddenly into the bottom of the pile. All the stones and water in the pile are blown out. The workmen and passersby are protected from the discharge. The larger stones seldom rise much above the top of the tube. If the tube is not down, having removed such stones as were a source of annoyance, the work of sinking is continued and the pile is pushed down to bed-rock, in the manner just described, leaving the way clear for the introduction of reinforcing bars, and the mortar used about them.

Of course, a variety of obstacles have been encountered in sinking these piles; there have also been offered a variety of objections to the form of construction. The question is asked: "How do you know when you have reached bed-rock?" We know by getting pieces of it up through the tube; we know by means of the tools provided for that purpose, and the pieces that are blown out furnish good evidence that the work is not being slighted.

Another question asked, is: "What do you do, in case you strike a boulder?" In quicksand, such as is found in the New York streams, the boulders lie at the bottom of the quicksand. Boulders in the quicksand district are on bed-rock, and three or more soundings will suffice to give a good idea of the size of the boulder, and if the pile comes on the top of a boulder, it is allowed to rest there, and we consider that the boulder enlarges the base of the pile by so much. If the piles have been chosen for a foundation situated in materials where an occasional boulder lies some distance above the bed-rock, it may be necessary to dig out the boulder or to adopt some other device; in some cases, two piles instead of one have been driven and joined together by a girder of short I-beams; that contrivance has taken the place of the one pile provided for on the plan, making no difference in the completed work, but costing the contractor somewhat more.

Another question is: "How do you know it will not rust out in a few years, and collapse?" The investigations I have referred to have satisfied me that there is no danger in such situations as piles have

been recommended for, and I believe that any engineer who takes pains to investigate will arrive at the same conclusion.

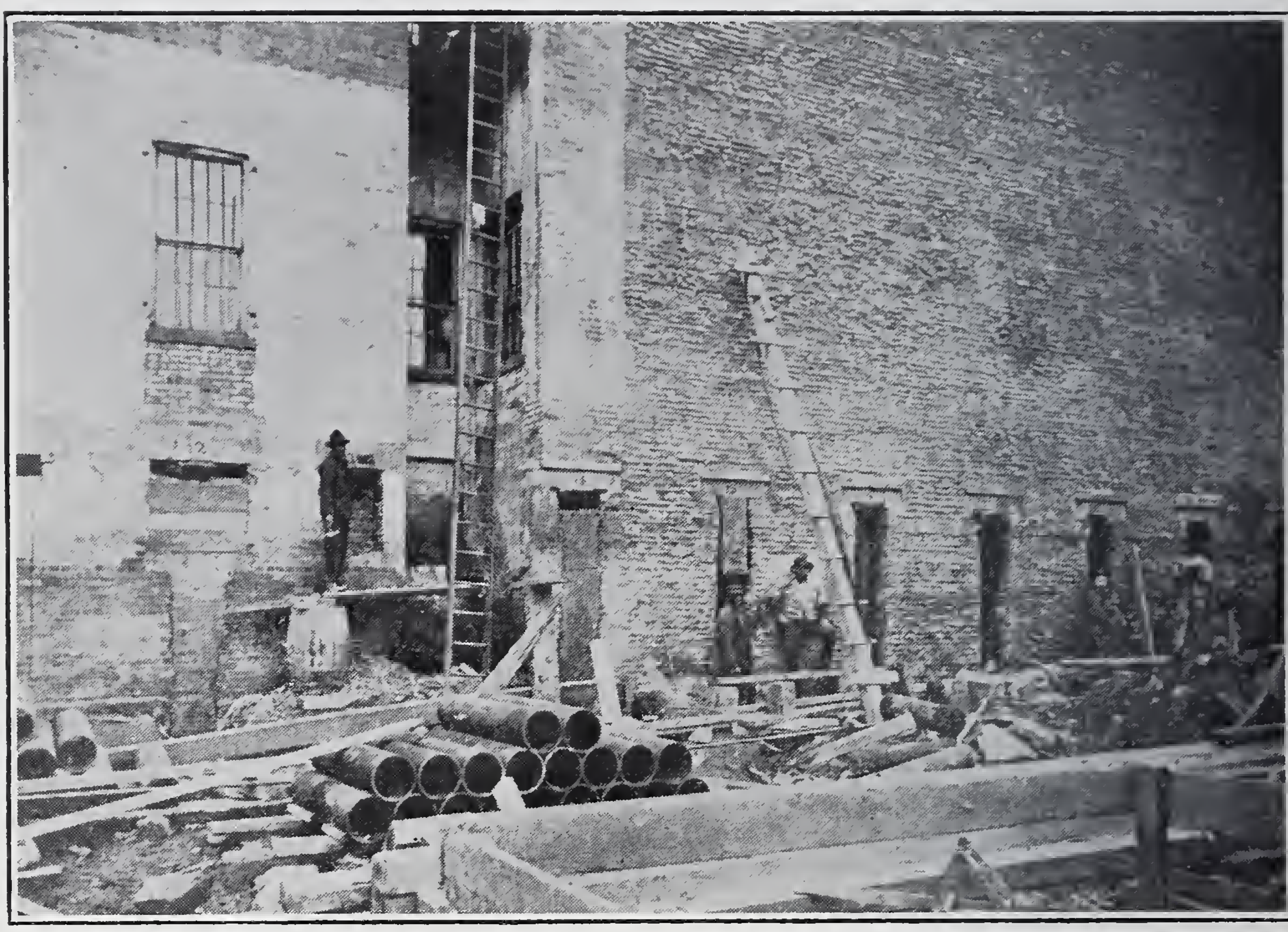
The maximum unit load on the steel is 6000 pounds. The maximum unit load on the concrete is 500 pounds. The engineer who hesitates to use a steel tube in the ground—the tube filled with steel bars—will sometimes place on top of his foundation pier a steel column—none too good in design—which will be loaded to 16,000 to 20,000 pounds per square inch. It will be conceded, I dare say, that the inner surface of the tube is proof against corrosion, as it is coated with Portland cement, and if one is not satisfied the exterior surface will be preserved, he can still allow something for deterioration, without running up the unit stress to a high figure.

The section of metal in the bars varies from one-half that in the tube to twice the section of the tube. The section of the bars is, of course, varied to suit the requirements of the load. In a single building the piles may be composed of five different sections, differing not at all in the tube, but differing in the number or diameter of the bars. The bars range in number from three to eight. The sections of pipe are joined by means of a splice, which can be driven half its length in to the section which is in place, and which will also enter half-way in the second section. This takes the place of the screwed coupling. It effects great saving in time and enables us to secure a full section of metal in the tube. An iron pattern is made, and from the iron pattern, crucible steel castings are secured. On opposite sides of the splice are triangular lugs. By means of a hacksaw two notches are made in the end of the tube 180 degrees apart. The lugs on the splice slip into these notches, the object of the lugs being to obviate the possible displacement of the splice. The tubes being faced at right angles, the pile is in a straight line.

Sectional piles, made up of short lengths, have been used to advantage in the shoring of heavy walls. I stated a little while ago that it was seldom necessary to shore adjoining walls, where these piles were used in the wall piers, but there are many situations where neither the pile described nor any other is suitable. In a case where, owing to the nature of the ground, it is desirable to have solid concrete piers, it may be necessary to invest several thousand dollars in shoring the adjacent walls. In such cases, a horizontal slot is made in the wall and a nest of I-beams, bolted together through the neutral axis, is placed in position and grouted; in the middle of these beams a vertical slot is cut down through the wall, to the earth, and a short section

of tubing put in place. The hammer is mounted, the jet pipe put in position, and the pile sunk until it is flush with the ground, when the second section is added.

The difference in machines is this: The machine used on shoring-piles is held in position by an air-feed working against the top of the opening in which the machine rests. Those used on other work are kept in place by dead weight. Shoring hammers sink 10 feet to 30 feet per hour. The sectional tube is forced down until it reaches bed-rock, when reinforcement is added. Of course, it is not practicable



Apartment House Supported upon Sectional Piles.

to run down long rods under a wall. The rods are either short sections with sleeves or some other form of coupling, or small rods are used in bundles. The rods are held apart from each other by means of separators; the remaining space is filled with concrete, after which a double cap is placed and thin wedges used to pick up the load. In some cases, in order to avoid using large diameters, a double tube has been used; an 11-inch tube inside a 12-inch tube, and sections made to break joints half-way, the completed work, of course, having the same appearance in either event.

In one case, after the shoring piles were in position, a trench was sunk, 18 feet below the base of the wall and parallel with the same, and the bottom of it driven full of timber piles.

For moderate and light loads, the shoring method described is not as cheap as shoring with needles, but in cases where it will be costly to enter the adjoining property, the sectional piles have much to recommend them and, where the loads are very great, they not only are more satisfactory to the engineer, but cost the owner less than to support the wall on steel beam needles.

Wall of Warehouse Supported upon Sectional Piles.

In cases where quicksand is present about the base of the pile and the rock is seamy, the removal of the water from the tube might cause a flow of quicksand into the latter. In such situations the water is removed by the admission of grout, to which I have already referred. I neglected to state that the grout is in an enclosed tank under air pressure. The tank is provided with a paddle-wheel, and the compressed air is admitted above the surface of the grout; the latter flows rapidly from the bottom of the jet pipe, and the tube is thus filled with liquid cement, after which the bars are placed in position.

In other situations, where no harm can come from removing the water, a form of steam siphon is used, and all the water drawn out.

It has not been found practicable to use a mixture of sand and cement, through the grout machine, or otherwise, as the sand and cement separate.

In a few instances logs have been encountered; these have been removed by means of heavy chisels or a rotating cutting tool. I know of no satisfactory tool for making such removals. In some instances boulders have been broken up with a heavy steel bar with a square end, which acts very much like a sledge-hammer. Boulders inside the tube are readily removed by compressed air, as already described.

In using such piles in a seaway, an outer shell should be provided, it seems to me, and the annular space between the two, from the mud-line up, filled with mortar and a quantity of steel wire. I have had better results with small reinforcement than with heavy reinforcement.

In sinking the piles a drop-hammer with a central opening has sometimes been used. A follower holds the top of the tube and receives the blows of the hammer. The jet pipe is used in the same fashion as with the pneumatic hammer. The drop-hammer has the advantage of enabling the contractor to care for a large job without delay. The castings can be secured in a short time and the necessary leads built to carry the hammer. The pneumatic machines are altogether more desirable for work on the foundations of buildings, and there are many situations, where these machines have been used, that a drop-hammer could not possibly have been employed.

The piles have been used in several hundred foundation piers, for buildings, and also for the foundations of pumping engines, generator sets, trip-hammers, and a variety of heavy machinery, and in situations where quicksand or other soft ground is met with, from the cellar floor to bed-rock.

In no instance, so far as I know, has any leak occurred in water-proofing after the machinery was put in operation. I think the piles furnish as unyielding a foundation as can be secured by other means, and it is entirely practicable to construct the foundation in an existing building.

In New York there is much machinery which has been provided with foundations, in cellars having head room of only 14 or 15 feet at the most.

In a few instances the piles have been provided with points and driven into masses of small boulders which have been dumped in the

process of filling ground. Such piles have been loaded with what the engineer in charge thought would be a safe load for the particular situation. In sinking these piles, the point has been connected with a force-pump, and in that way a stream of water projected from the point of the pile, the latter having to pass through overlying earth and rubbish, before going among the small boulders, with which the fill has been made.

In many situations in New York the piles are not at all adapted for use, because there is a mixture of clay and other material containing boulders to as great an extent as a pudding contains plums. No one can say whether or not it is practicable to use the piles until soundings have been made on the sites of the piers. Sometimes soundings are not to be had at the time work on the plans is begun. It often happens, over there, that the architect gets the plans completed without knowing anything about the nature of the subsoil.

DISCUSSION.

W. F. Ballinger.—I would like to ask Mr. Clark whether or not he figures the piles as columns with a bearing entirely on rock, and if the bearing is 6000 lbs. per square inch on the tube and on the rock, is there any cutting effect? The rock is surely not as strong where the point rests upon it as the steel, consequently I think if it were loaded to that extent there would be some cutting; also, about what is the maximum depth that has been penetrated?

E. G. Perrot.—Regarding the use of galvanized pipes for piles, I would state that the concrete pier at Atlantic City is built upon concrete piles enveloped with heavy galvanized pipe having wooden points, and I was told by the engineer that they calculated the pipes would rust out, lasting about twelve years, even if galvanized. They figured on the concrete as carrying the load. I would like to ask Mr. Clark whether he has taken into consideration the effect of electrolytic action on a pile when it comes above the surface of the cellars, or anywhere near the surface of the ground; would it not be well to put a concrete jacket around a pile where there is any electricity or air? Our experience is that there is a great deal of gas in city streets, and I think it would be better to construct a pile with an outer shell thinner than the main shell and pour thin mortar between two of them.

My idea as to the method of calculating the type of pile we have under discussion tonight differs from that of the author by involving the bursting effect of the load on the pile. I think the question of the capacity of the rock is solved by the answer Mr. Clark has given, and if we take his answer in regard to rock, which is apparent to any one who thinks about it, why will not the concrete carry as much as the rock without the steel rods inside the tube? If the pipe was designed for resisting the bursting pressure, and the concrete put in, in any form and there confined, I think the pile would be more scientifically designed, and the question

of compression on the concrete would enter very little into the figures. The whole effect of loading up rings or rods is only adding to the compressive strength, and is not an economical way of using the steel.

The United States Government tests, at Watertown, on columns 8 feet long and 10 inches in diameter with hoopings 1½ inches wide, 2-inch centers, show a compressive strength of over 5000 lbs. per square inch. If you can get 5000 lbs. with a 1–2–4 concrete with thin hoops, 2-inch centers, I would think that in a pipe ½ inch thick and solid, where the concrete could not spurt out between the hoops, you could get any carrying capacity you wished, on the same principle that the bearing point of the pile was sufficient, because the rock could not get out below. Why not do away with the rods and use only the concrete?

Henry Hess.—Can you give an approximate figure of cost—maximum or minimum—for say a unit load on your system of piles per unit depth?

R. G. Develin.—Can you use the system in any place except where you have rock underlying?

H. F. Porter.—It would seem to me that the carrying power of this pile would be scarcely benefited by the presence of steel rods or when the direct load of 5000 or 6000 lbs. is counted as its carrying capacity. Is its carrying capacity not due in a large measure to the concrete? I know of a case in Chicago where a concrete column—much the same design as your pile—was loaded up to something like 5000 lbs. per square inch without disrupting the concrete, but the method used had to be stopped because the method was stretched to its utmost limit. Your pile would require the enveloping cylinder which Mr. Perrot mentioned, with two or three inches of concrete in between. It would not do to have it honeycomb in the course of time, otherwise the carrying capacity of your pile would be gone. Certainly I do not see how the cast-iron on the top can distribute the load into the steel core and the concrete simultaneously.

E. M. Nichols.—Have you any experience with using tubes for your reinforcement inside and do you not think it would be better to use inside of the large pipe an 8-inch and a 4-inch tube, and fill it with grout?

J. G. Brown.—With some experience in dredging I found it was not unusual to find clay, then a layer of hardpan 4 inches thick, then perhaps gravel, and then sand. Assuming a condition of this kind, how could you determine when you had passed through the hardpan? I have seen dredges working on this for several hours before breaking through, and how could you identify it? You might find different materials. Take, for instance, the tunnel of the Pennsylvania Railroad; there were quite a number of borings made in their preliminary work and it was often a question whether they had struck a boulder or whether they had struck bed-rock, yet they used Diamond Core drills. The only thing we could do was to assume that after we had continued 15 feet through stone we had bed-rock. I know we have gone through boulders and drift rock 5 feet thick and then continued through silt and sand. Had we assumed any depth of stone less than 5 feet we would have considered these boulders as bed-rock.

Another question is the filling in the inside of the pipe. From the cut here I presume that the grout going through and mixing up with the water would separate the cement, and you would have considerable laitiance, which being very weak would reduce the bearing power of the interior.

W. C. Furber.—I would like to ask whether in driving these tubes, when

they strike the rock, if it does not have a bad influence on the threads of the pipe and is liable to split the joints apart? What material is the pipe that you use?

Mr. Clark.—Answering the question as to how the pile is calculated: It is usually figured as a column having a bearing on rock. Frictional resistance is not considered. Tubes have been sunk about 70 feet below the surface, and probably about 55 feet below the level of cut-off.

Loading the bed-rock, in the case of these piles and small concrete piers, is analogous, it seems to me, to loading a steel pin placed in the hole in the top of an anvil. You may load the pin as heavily as your ingenuity will permit, but you neither punch a hole through the anvil, nor cause the same to flow. If cubes of wood show resistances of 5000 to 8000 lbs. per square inch, it seems to me that, if we could have a testing machine on the surface of the bed-rock, with an overlying soil 50 feet in depth, and introduce the plunger of the testing machine into the rock a distance of 6 inches to 6 feet, we would wreck the machine before we could push the bed-rock anywhere. I cannot imagine the rock as failing under those conditions. There is nothing about it analogous to the testing of a cube. There is no place for the rock to go to.

It has been proposed, before the Committee on Revision of the Building Code in New York, that the new code either fix the load upon hard bed-rock at some very high figure, or else allow the engineer to load according to his judgment.

Regarding the use of galvanized pipes, I dare say that they have been used to some extent; but I have not seen them used. In a situation where the tube could rust, it seems to me that it would not make very much difference whether it was galvanized or not. If I were to put the tubes in salt water and wanted to make sure of their remaining indefinitely, I would put down an outside tube and fill the annular space with cement mortar. In some parts of the country there are underground streams running through gravel. In such situations the stream is constantly bringing in air, and I would not expect that iron or steel would remain permanently in good condition. In New York, however, the old waterways are filled with quicksand and clay, and perhaps some other material, and there is no movement of the water sufficient to introduce fresh air; in fact, when the ground is opened the air in the shaft sunk through it is decidedly bad; the water is almost black.

In a building, we have a waterproof envelop passing through the cellar floor and up through the walls of the building to the curb level. It seems to me that with such an envelop and with streets paved with asphalt, overlying beds of Portland cement concrete, it is practically certain that air will not reach the metal surfaces.

On the lower parts of the piles that I saw at Coney Island were plainly to be seen the fine marks made by the straightening rolls, while the portions between the high and low water marks were so corroded as to leave openings through which a man might run his arm.

In regard to Mr. Perrot's suggestion as to the use of an outer shell, I may state that the difficulty with a thin shell pile lies in the introduction of the shell. The frictional resistance of the soil encountered in Manhattan varies from about 400 to 1200 lbs. per square foot. I have taken pains to ascertain the resistance of cylinders varying from 9 inches to 6 feet or more in diameter. In order to get a tube down through the ground to bed-rock it is necessary to have consider-

able stiffness. In one form of construction employed slightly in New York very thin tubes have been introduced on a metal punch, and the punch afterward withdrawn; but the resistance has sometimes been sufficient to tear the thin metal.

In regard to Mr. Porter's statement, I do not feel myself competent to deal with the theory of action, in columns of such construction. I can only relate what has been done and give the results of some tests. I know that spirally wound concrete columns have tested very high, and it seems to me that the loading of the concrete, in such a column as I have described, might run very high without any danger. I have had prepared, for testing, several tubes partly filled with mortar and provided with a metal plunger; within a short time I expect to have those pieces tested, and hope to find out what will happen when the load is applied to the steel plunger acting on concrete within a seamless steel tube. In this connection I will say that I have had occasion to use concrete in which metal was substituted for stone or gravel, and now have some 6-inch cubes which will soon be tested; these cubes have been made up of metal instead of stone. I made use of such concrete in places where it seemed necessary to have high bearing capacity in a short time. I do not know that it is any better than grout or other materials, but I hope to find out.

The largest number of tubes we have used is two, an outer and inner tube, separated by steel balls or rivet heads. The use of both 8-inch and 4-inch inner tubes would certainly make a fine job, but it would materially increase the cost. The only practical scheme that has occurred to me is to place inside the steel tube a cast-iron tube in sections, having the ends faced after the fashion of the outer tubes. Probably many engineers would object to the use of cast-iron.

Answering Mr. Hess' question as to the cost of the piles, the quantity of work done to date has not been great enough to afford many jobs that were quite similar, but I have tried to get at the cost, roughly, by multiplying the load by the average length of pile required—call it "foot-tons," if you like. The cost of such work as has been done in Manhattan, reduced to that basis, varies from 6 to 10 cents per foot-ton or unit.

Answering Mr. Develin's question as to the universal application of these piles, would say that no attempt has been made to use the piles of high capacity except where the lower end reached bed-rock. If used in ground where it was necessary to depend upon surface friction alone, I think the piles would have to be reduced greatly in cost to find favor.

I think that a thoroughly good job can be made without interior bars, and that there would be nothing wrong in doing as Mr. Perrot suggests. At the same time I believe that they may be used and an additional load imposed because they are there. Furthermore, to consider the practical side of the matter, it is necessary to make concessions to prejudice and mode of thought, in introducing something that differs considerably from the forms of construction previously used. If I knew that the bars employed in the pile did not render it any more valuable, I should doubtless have a hard time to convince many engineers and architects that such was the case.

Concerning the material penetrated, of course positive knowledge can only be secured through a considerable number of borings, and a foundation is seldom designed without having borings made. At the lower end of Manhattan Island

the bed-rock is overlain by hardpan of very compact character. Last year, at the corner of Wall Street and Broadway, a foundation was constructed for an eighteen-story building, using the tools described. The tubes went through the hardpan found there and into the bed-rock. Pieces of the latter were brought up through the tubes.

The cut referred to is more or less misleading. The grout is not introduced into the bottom of the tube except when an inflow of quicksand is feared or thought possible, and when so introduced, it is put through a 2-inch or 3-inch pipe under pressure of compressed air, and flows out slowly at the bottom of the tube. It remains there, being of a much higher specific gravity than water. The water runs out gradually at the top of the pile and then concrete or mortar is lowered into the grout and some of the grout is allowed to waste over the top of the pile. I think that when it is properly done there is very little danger of the quality of the concrete being impaired because of the introduction of grout in that way. In many situations grouting is not worth while; were it not done as a precaution, it would not be done at all.

As regards the splitting of pipe, due to the weakening influence of threads, I would state that there are no threads on the pipe. The several sections of the pipe are faced and abut. On reaching bed-rock the chisel is worked more vigorously than the hammer. The hammer strikes a comparatively light blow. The chisel is chiefly designed to remove the rock expected to be found and, upon reaching rock, it is practicable for an experienced foreman to tell what kind of rock has been reached. The chisel is worked until the rock is chiseled out and the tube has been brought to a bearing all the way around. There are few places where the top of the rock is very hard.

Wrought-iron and open-hearth basic steel are the materials of which the pipe is made. At first we used the Bessemer pipe. Most of the pipe used now is open-hearth steel, not less than $\frac{3}{8}$ inch thick

Paper No. 1049.

DREDGING EQUIPMENT ON THE PANAMA CANAL.

F. B. MALTBY.

(Visitor.)

Read January 4, 1908.

Much has been written and told concerning the progress of the work in the construction of the Panama Canal. Long articles have been written and elaborate talks given by people who have sometimes had an acquaintance on the Isthmus extending over as long a period as a whole week. These expounders of the "truth concerning Panama" usually cover the whole canal from end to end and all features concerning its construction. The writer feels that the subject is a very large one, and will attempt to describe only one feature of construction—that of the design, construction, and operation of the plant used in dredging operations.

Most visitors to the Isthmus are impressed with the spectacular work of the steam shovels and much has been written and said concerning their size and "almost human intelligence," etc.

Most articles or lectures that I have seen or heard have been profusely illustrated with various views of steam shovels, while if any mention at all is made of dredges it is very brief.

The writer recently saw a picture shown at a lecture on Panama of one of the old French dredges, which the speaker described as having been abandoned, while in fact the photograph was taken while the dredge was in operation and removing about 60,000 yards of mud per month.

There is no desire to detract in any way from the importance of the work of the steam shovels. Their operation is indeed impressive and the results obtained are remarkable considering all the circumstances, but the ordinary observer does not appreciate the fact that with all the noise and bustle and activity a shovel may be removing 700 or possibly 1000 yards per day while a dredge with no fuss and few men may be removing four to six times as much or more.

The writer during a connection of about two and a half years with the Isthmian Canal Commission, most of which time was spent on the Isthmus, had charge of the design, construction, maintenance, and

operation of the dredge plant employed, and it is proposed to give a brief description of this machinery.

There are in use, or being built, four distinct types of dredges of entirely different characteristics: First, the old French ladder dredges; second, American dipper dredges; third, sea-going suction dredges; fourth, pipe-line suction dredges.

The so-called old French ladder dredges are those which the Americans fell heir to when the canal property was purchased from the French canal company. There were some sixteen or seventeen of these dredges, of the endless bucket type. They vary somewhat in detail, but are all of the same general construction. The digging apparatus consists of an endless chain of buckets holding about 14½ cubic feet each. This chain of buckets is carried by a box girder hinged at the top and of sufficient length to enable the dredge to work to a depth of about 30 feet. The buckets discharge into chutes leading over the side of the dredge and into barges alongside.

The chain of buckets is driven with a pair of steeple compound condensing engines, which are connected with the top tumbler wheel either through gearing or by friction wheels and large sprocket chains. Steam is supplied by Scotch marine boilers working under a pressure of 70 to 80 pounds. The hulls are of genuine wrought-iron, not steel, and some of them were supplied originally with propelling machinery, but this has been taken off. The hauling and hoisting winches are simple but cumbersome and 1¼-inch chain is used for hoisting the ladder as well as for moving and maneuvering the dredge. No quarters were provided for the crews. These dredges were built either in Belgium or in Scotland. Some of them had been pretty well worn out and were of little value. Most of them were in a remarkably good state of preservation, although most of them had not been in use for at least eighteen years. The woodwork was entirely rotted away and required renewing throughout. The machinery had been carefully laid up and painted and had been well cared for. It required only cleaning up, packing of joints, and occasionally a rod needed truing up. The hulls, on account of being wrought-iron, had corroded very little and were practically as good as new.

One of these old dredges was rebuilt at Cristobal and put into operation in May, 1905, and a second one was afterward rebuilt and repaired. The Panama R. R. Co. was operating one at the Pacific terminus and it was turned over to the Canal Commission in June, 1905, and a second and a third one have been rebuilt at that end.

These dredges of the non-propelling type have hulls of rectangular shape, about 114 feet long, 32 feet wide, and 12 feet deep. The engines operating the chain of buckets are of about 180 H. P. and are operated condensing. These dredges have no means for breaking up the material to be excavated other than the buckets themselves, and consequently their digging capacity or the ability to force the buckets into hard or compact material is not very great. For these reasons their capacity per day varies with the material to be excavated.

At La Boca, the Pacific terminus, there are two of these dredges in operation, working twenty-four hours per day and six days in the week. During the month of October, 1907, one of them removed 143,222 and the other one 143,885 cubic yards, an average of about 5300 cubic yards per day. The maximum daily output in November was 6907 yards and 7556 yards respectively. The material handled is mud with a very considerable portion of sand, very easily excavated and handled with this type of dredge. During October, 1907, one of this same type of dredges removed 133,064 yards from the new channel in Limon Bay, or the Atlantic terminus. The reduced output below that of the dredges on the Pacific side is due to a greater seaway on the Atlantic side and also to the fact that the mud encountered is softer, and while it is easier to excavate, it is so soft that it will not pile up in the buckets and more or less is lost during the passage of the buckets through the water. The capacity of these dredges excavating in coral rock is reduced by about one-half. The material excavated is taken out to sea and dumped into deep water, the length of haul varying from two to four miles.

The dredges are served by self-propelling hopper bottom dump barges, which are also a part of the old French equipment that has been rebuilt. These barges have a hopper capacity of about 225 cubic yards of mud, measured in place. They have steel hulls about 145 feet long and are driven by twin screws and compound condensing engines. The hopper doors are operated by hand winches.

The operation of these old dredges has been rather surprising and very satisfactory. Their machinery, though cumbersome, is very simple, and very little trouble has been experienced through break-downs. The buckets have cast-steel backs with $\frac{3}{4}$ or $\frac{7}{8}$ steel fronts and bottoms riveted to them. They have an extra cutting tip or edge of 1-inch steel. The eyes in the links and bucket backs forming the chain are bushed with steel and have steel pins. These bushings and pins wear very rapidly, but their renewal is a very simple and inexpensive matter.

The bearings for the lower tumbler wheel, which are constantly working in sand and grit, also wear very rapidly; the journal boxes are of cast-steel and made solid and without any provision for taking up wear. They are usually allowed to run till the boxes are nearly or quite worn through on the bottom.

The cost of handling material with these dredges, including the cost of operation, superintendence, all running repairs, and the cost of operating the barges, is between nine and ten cents per yard, though monthly costs have gone as low as five cents per yard. This cost does not include any proportion of first cost or depreciation or the first cost of extensive rebuilding.

It is evident that for excavating soft material to a moderate depth this type of dredge has certain advantages that are not appreciated in this country. They are very similar to the gold dredges that have been so extensively and successfully used throughout the West.

The second type of dredge in use is the dipper dredge. This is strictly an American type of dredge and was originated and has been used in this country to a greater extent than any other type in use. They can be briefly described as a steam shovel gone to sea, as they have all the characteristics of a steam shovel with the parts made usually much heavier and with a radius of action greater than a steam shovel. Three of this type of dredge have been built and are in operation on the canal, one on the Pacific side and two on the Atlantic side. Two of them were built by the Atlantic Gulf and Pacific Dredge Co., after designs made by A. S. Robinson, and the other one by the Featherstone Foundry and Machine Co. All three are of the same size and general construction. Steel has been used throughout, except in the spuds and dipper handle, which are of wood, the latter lined with steel angles and plates.

They have steel hulls 110 feet long, 37 feet wide, and 9½ feet deep, and are proportioned to excavate to a depth of 40 feet of water. They have dippers with a capacity of 5 cubic yards for excavating in sand or mud and have extra dippers of 3 cubic yards capacity and fitted with very heavy manganese steel teeth, to be used for continuous operation in rock.

The main engines operate the hoisting and backing drums and also the drums for handling the spuds, while the swinging is done with an independent engine. They are equipped with independent capstan engines and electric light plants. Steam is supplied by Scotch marine

boilers at a working pressure of 150 pounds. The booms are of very heavy construction and about 52 feet long and are carried directly on the turntable without any overhead gallows frames. The spuds are of Oregon fir, 60 feet long. On two of the dredges these are single sticks 36 inches square, while on one of them the spuds are built up and are 42 inches square. The main hoisting lines are crucible steel cables leading direct to the dipper without the intervention of any purchase blocks, and all sheaves over which the line passes are 6 feet in diameter. On two dredges two cables, each $1\frac{5}{8}$ inches and laid side by side, are used, while on the other one a single cable $2\frac{1}{4}$ inches in diameter is used.

The engines, gearing, and drums are proportioned to give a pull on the hoisting line of about 90,000 pounds. These dredges were built under general plans and specifications prepared by the writer, the details being left to the builders.

The principal advantage of this type of dredge lies in its ability to dig in hard material. It has been found quite possible to excavate coral rock without blasting, though the progress of the work is expedited by a small amount of shooting to loosen up the ledges and to permit the dipper to get a better hold on the rock. A somewhat smaller crew is required than on a ladder dredge, though the operator must be a much higher paid man, as the capacity of the machine in any given material depends almost entirely on the ability of the operator to keep it in constant and rapid operation.

Owing to some mechanical defects the operation of these dredges has not been as entirely satisfactory as was hoped, though I understand that these have been remedied to a very large extent. They cost about $102,000 apiece delivered on the Isthmus. During twenty days in the month of October, 1907, one of these dredges removed 70,000 cubic yards from the channel at the Pacific terminus, while the maximum daily output in November was 4456 cubic yards.

The third type of dredge, and possibly the most important, owing to their size and cost, in use on the canal is the sea-going suction dredge. Two of this type have been built, one for each terminus, and one of them has been in operation at Colon since September, 1907. The second one, the "Culebra," reached La Boca under her own steam December 28, 1907, after a voyage of about 12,000 miles, much of it through heavy weather.

These dredges are designed to operate in the harbor entrances to the canal and are therefore built self-contained and are able to work in a considerable seaway. In general design they are very similar

to the dredges "Manhattan" and "Atlantic," in use in excavating the new Ambrose channel to New York harbor, and to the dredge "Delaware," in use in the Delaware river. They differ from these dredges in the detail of their dredging machinery and also in their equipment and arrangement of quarters.

Their hulls are of steel, 274 feet long between perpendiculars and 288 feet long over all, with moulded beam of 47½ feet and depth of 25 feet. The hull framing is made in accordance with the rules of the American Bureau of Shipping for vessels of class A. 1. They have twin screws and are propelled by compound condensing engines $22 \times 44 \times 30$ inches stroke.

The dredging machinery consists of two 20-inch single suction centrifugal pumps direct connected to compound condensing engines running at from 160 to 170 revolutions per minute, and at these speeds developing from 440 to 460 I. H. P.

The centrifugal pumps are located on each side of the ship a little aft of amidships. They have inclosed cast-steel runners about 72 inches in diameter with six blades about 19 inches wide. The suction from each pump passes through the side of the ship a little below the loaded water-line and is joined to the suction pipe through a swivel elbow. The suction pipe is $20\frac{1}{4}$ inches inside diameter, $\frac{3}{8}$ inch thick, and the sections are joined together by forged steel flanges welded onto the pipe. These flanges and the welded point have a greater strength than the pipe itself. The suction pipe is about 63 feet long over the suction shoe and the dredge can excavate to a depth of 40 feet of water. The pumps discharge into sand bins having a nominal capacity of about 2000 yards. Steam is supplied by four Scotch marine boilers 14 feet in diameter, 12 feet long, under a working pressure of 150 pounds.

The dredges are equipped with the usual condensers, pumps, and auxiliary machinery, and in addition have electric lights, evaporators, and a complete ice-making and refrigerating plant.

The dredges are entirely self-contained and are able to operate for a week or more with the coal and stores which they will carry.

Quarters are provided for a crew of about fifty-seven men. The details of the dredging machinery, sand-bins, and arrangement of quarters, etc., were designed by the writer, while the general construction follows that of the dredges previously mentioned. They were built by the Maryland Steel Co., at Sparrows Point, Md., and cost about $724,000 for the two.

The operation of the one now in commission has been most satisfactory, and there is every reason to believe that the second one will be equally as successful. On their tests they handled from 1600 to 1700 yards of sand and mud per hour.

The centrifugal sand pumps carried a vacuum on their suction side of from 26 to 28 inches. Their nominal capacity is about 2000 yards per hour in clean sand or sand with only a small proportion of mud.

The trip from Sparrows Point to Colon, a distance of 1906 miles, was made in eight days and nine hours, including about half a day that she was hove to on account of a storm, or an average of 9½ knots per hour.

The dredge is operated for twenty-four hours per day for five and a half days per week, Saturday afternoon being used for coaling and taking aboard stores.

During the month of September, with a green crew and new machinery, 266,000 yards measured in place was excavated in the harbor at Colon; in October 273,500 yards and in November 304,000 yards.

The material is mud and does not readily settle in the bins, though it is very readily excavated. By actual measurement it has been found that the pumps have handled as high as 87 per cent. of solid material. The length of haul to the dumping-ground is two to three miles. In commenting on the work of the dredge during September the "Canal Record" estimated that the excavation and disposition of the same amount of material from Culebra cut would have required the work of fourteen steam shovels, thirty locomotives and work trains, and about fifteen hundred men. The crew of the dredge consists of fifty-seven men.

The fourth type of dredge to be used in the canal is the pipe line suction dredge, or a suction dredge which deposits on shore, through a pipe line, the excavated material. The French company had several small dredges of this type, used for re-handling material, but they were never very successful in operation on account of the design of the pumps.

These pumps had suction and discharge pipes 16 inches in diameter. The pump runner was about 24 inches in diameter and had blades about 4 inches in width. These proportions will perhaps be better appreciated by comparing them with a pump for the same sized discharge pipe which was put onto one of these dredges which had a runner 69 inches in diameter with blades 11 inches wide inside the shroud.

One of these small dredges was rebuilt and a pump of the size just mentioned put on it. This dredge has been used in filling material into the low ground adjacent to Colon and in opening a channel in the old canal between Cristobal and Gatun, portions of which had filled up. The material from the channel was pumped ashore.

It is proposed to build the great Gatun dam by the hydraulic method or by pumping the material into place. The hydraulic method of dam construction is not new and has been extensively used in the West, but usually in localities where flowing water with a source at sufficient elevation is available for transporting the material. It should, however, make no difference in the success of construction of this nature whether the water is secured from mountains under a sufficient head to give the necessary velocity for transportation or this velocity is given by pumps. For this purpose two dredges are being built, which will first borrow as much material as can be had within reasonable distance of the dam, and will then re-handle and pump into the dam material excavated from the canal and brought to the site in dump barges.

These dredges are of steel, 135 feet long by 36 feet wide and 9 feet deep. They have a single 20-inch pump with double suction, driven by a pair of tandem compound condensing engines developing about 450 I. H. P. The suction pipe is provided with a cutter driven by an independent engine. The cutter and supporting frame are very heavily built and braced and designed for excavating very stiff clay. The discharge pipe is carried on floating pontoons to the shore line and from there to the point of discharge is laid on the ground.

It is not expected that it will be possible or advisable to pump material into the dam and up to the full height with a single pump. It has been found that about 75 feet head against a sand pump is about the economic limit, as beyond that the necessary peripheral velocity of the pump runner becomes so high that the wear is abnormal. By "head" is meant the total head against which the pump is operating, and will consist of friction in the pipe, velocity head, and the actual lift or static head.

When the head has reached the maximum economic limit it is proposed to use a relay pump. This will be a pump similar to the one on the dredge, but motor driven, and will thus not require any steam plant or foundation, and but little attendance. It will be placed at the end of the discharge pipe, which will lead directly into the suction side of the pump. Its discharge pipe can be extended till the head on

the second pump has reached the same limit, when another pump can be added, and this repeated as often as necessary.

It is, however, improbable that more than two pumps on one line will be needed. These dredges have not been completed and are not in operation. Two of them are also being built for the construction of the dams at the Pacific end of the canal, as proposed by the Board of Consulting Engineers. The Canal Commission has just recommended the construction of locks at Miraflores instead of La Boca, which will obviate the necessity of dams near La Boca, but will necessitate the excavation of several miles of sea-level canal, for which work these dredges are admirably suited.

As tending to show the relative capacity of the dredging plant I have described, I will refer to the amount of excavation during the month of November, 1907. During this period the three ladder dredges, three dipper dredges, and one sea-going suction dredge excavated and removed 792,000 yards, while the total amount removed by steam shovels from the Culebra division was 788,000 yards, or the seven dredges removed 4000 yards more than forty-two shovels. Of the total amount dredged, 304,000 yards was taken out by the dredge "Ancon," which is at the rate of nearly 600 yards per hour for every working hour she was in commission during the month. The average amount excavated per day of eight hours per shovel is 784 yards, or 98 yards per hour.

It is realized that it would be impossible for the dredges to do the work performed by the steam shovels, but it is equally true that the steam shovels cannot do dredging work.

There is no desire to detract in any way from the work of the steam shovels, but I wish to emphasize the fact that they constitute only a part of the equipment for excavating the canal.

COLEMAN SELLERS, D.Sc., E.D.

HONORARY MEMBER OF THE CLUB.

Born Philadelphia, January 28, 1827.
Died Philadelphia, December 28, 1907.

THE death of Dr. Coleman Sellers at the ripe age of fourscore years adds another name to the final record of eminent American engineers and men of science, while a busy and useful life terminates its tireless activity.

The particulars of the career of Dr. Sellers have been so fully described in contemporary journals that biographical details would only be a repetition of what has already appeared in print.

With an ancestry that held an honorable record for several generations, the influences of heredity were reflected in the precocious talents of the boy and the genius of the man in whom these inherited traits were developed by education and practice. His versatile accomplishments were illustrated in such a variety of ways as to prove a source of wonder to those who had known only the work of the trained mechanician and engineer.

The hours spared from his professional labors were largely devoted to personal research, and his early works in microscopy, photography, etc., were not merely the efforts of the ordinary amateur, but left a permanent impression in the development of the arts.

The fact was that his mind was always busy. Even apparently trivial things did not escape his attention. While toying with a few pennies in the odd moments of a street-car ride, he conceived the idea of a variable feed movement for the machinist's lathe, a device which was extensively applied at the time.

Deftness of hand supplemented the alert mind, and he was prompt in mastering appliances adapted to facilitate his work; and this trait was so dominant that it even influenced his pastimes. Many who recall the arduous period of our Civil War can remember his skill in parlor magic or sleight-of-hand—a form of amusement to which he contributed several novel devices.

This manual dexterity constantly manifested itself throughout his life; he was quite skilful with the telegraph instrument and with

the typewriter, in the early days of these devices, and as his sense of vision became seriously impaired, shortly before his death, his indomitable perseverance led him to master the art of reading for the blind, and he read by the sense of touch alone, in both English and French, in his eightieth year.

The important work of his professional career began in 1856, when he became allied with the firm of his kinsmen, William Sellers & Co., as designer and chief mechanical engineer. Prior to this period, the production of machine tools was in the formative stage. A new era began, in which the modern tool replaced the cruder products of the preceding time.

For the following thirty years the productions of these shops bore the impress of the mechanical and artistic skill of Coleman Sellers, and contributed much toward giving the name of Sellers in America, like that of Whitworth in England, a leading place among the pioneers of the new development.

Rational design was combined with graceful outline, and novel mechanical applications to further precise and automatic action all blended in a harmonious whole, which made the machine tool a pleasing object in the workshop, and an instrument of increased utility to the workman. The impress of the master's hand, the fertility of his mind, were always in evidence; and it would require a special treatise to adequately portray the great work accomplished in this era of his life, which covered a wide field and a great variety of product.

In 1886 ill health compelled him to sever his connection with the firm of William Sellers & Co. to resume his labors in new fields after a brief vacation.

He was induced to accept an appointment as non-resident member of the faculty of the Stevens Institute of Technology, filling the chair of Professor of Engineering Practice, and holding meanwhile the office of Professor of Mechanics at the Franklin Institute. His lectures and addresses before both these bodies were models for lucidity of thought and expression.

At this period the subject of utilizing the waterfall at Niagara as a source of power had been vitalized by the proposal of Thomas Evershed to establish a hydraulic system on the general plan of location that was subsequently adopted, and Dr. Sellers was commissioned by the interested capitalists to examine and report on the feasibility of the scheme. Realizing the momentous character of the undertaking, he suggested the creation of an international commission of five mem-

bers as advisers to formulate a general plan of operation. This body was created with the eminent engineer and scientist, Lord Kelvin, as Chairman, and Dr. Sellers the only American member.

The subject involved novel projects on a vast scale, and for some of these there was but meagre precedent. The distribution of the power through the medium of compressed air was discussed and soon rejected, and an electric transmission definitely chosen.

The discussion then turned upon the kind of current to be employed. Various direct-current systems were advocated, and the voltage, phase, and frequency of alternating currents were subjected to careful review. It will be remembered that few cases were then extant of electric dynamos operated by water-power; and few, if any, of these had the accuracy of speed control so essential for alternators especially. No electric plant had been projected approaching the power of the Niagara dynamos.

The large alternators designed by Ferranti for London service were not built until 1889, the year that the Niagara Commission was created, and they were intended for lighting purposes only.

In fact, the alternating current motor was not satisfactorily developed at that time and its future condition was by no means definitely assured. There appeared also to exist some exaggerated ideas of the losses involved in transformation by the induction coil.

For a time the choice of the particular current to be selected was in doubt, especially when the formidable influence of Lord Kelvin was cast in favor of the direct-current system; and he, it is said, moved the adoption of a resolution to abandon the further consideration of other than direct-current systems.

Dr. Sellers, on the other hand, had observed the growing tendency toward the introduction of the alternating current, and foresaw and appreciated the elasticity of that system, and its greater adaptability to the long-distance transmission of power. He defended his views with such skill as to secure the approval of the commissioners. In the light of later developments, few will question the wisdom of the choice. Dr. Sellers' view subsequently received the generous approval of Lord Kelvin.

The history and development of the power plants at Niagara have been so fully described elsewhere that it is unnecessary to repeat the story here. Suffice it to say that, without any derogation of the preliminary work done by his colleagues on the commission, the execution of this important and novel work will always reflect high credit on the intelligence and foresight of Dr. Sellers.

When the commission had fulfilled its purpose and disbanded, Dr. Sellers was appointed chief engineer of the company, and from that time on, great responsibilities were placed on him, which involved not only his own reputation but also the future welfare of the corporation which relied upon the accuracy of his judgment.

If the Scriptural phrase, "All things are possible to him that believeth," is interpreted aright, it can be applied to an endeavor of this character—where firm belief is based on an intelligent and well-founded conception of the object in view, faith in the final result, and an energetic prosecution of the work to its successful conclusion. "He who believeth" must also be dominated by an intellectual courage from which all doubts and waverings are eliminated.

"He either fears his fate too much
Or his deserts are small
Who dares not put it to the touch,
And win or lose it all."

Measured by these standards, the reputation of Coleman Sellers will endure as a great mechanician and engineer, entitled to generous recognition by the engineering profession and by his countrymen.

Dr. Sellers received the honorary degree of Doctor of Engineering from the Stevens Institute of Technology in 1887, and the degree of Doctor of Science from the University of Pennsylvania in 1899.

He served as President of the Franklin Institute; President of the American Society of Mechanical Engineers; President of the Pennsylvania Museum and School of Industrial Arts; Vice-President of the American Philosophical Society; and was a member of many other kindred societies, both in this country and in Europe.

Wilfred Lewis,
James Christie,
Edwin F. Smith.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, December 7, 1907.—President Quimby in the chair. One hundred and eleven members and visitors present. Minutes of previous meeting approved as printed.

No additional nominations for officers were presented.

Dr. Spangler made progress report of Finance Committee.

Report of Tellers read, showing that John E. Allen, C. C. Anderson, Herman Claude Berry, Herbert G. Campion, Chas. E. Carpenter, J. L. E. Cheetham, E. E. Dunlap, Chas. Frommer, E. L. Ingram, Arthur C. Jackson, Charles A. Judge, Alfred Kauffman, Benj. G. Love, J. W. E. Love, Harry T. McDevitt, C. I. Morris, F. G. Myhlertz, Herman Nieter, Harry F. Porter, L. H. Rittenhouse, William T. Ruth, Russell B. Smith, Arthur L. Terry, Jr., Willard S. Tuttle, F. V. Warren, and Charles C. Willits were elected to active membership; that C. A. Bockius, Gordon Brandes, Daniel L. Britton, Charles H. Cox, and Jas. F. Haldeman were elected to junior membership; that Chas. C. Clausen, S. V. V. Hoffman, Frank H. Stewart, and W. W. Umbenhauer were elected to associate membership.

President Quimby made an appeal for more general presentation of papers by members.

Mr. A. B. Clark, of New York City, read paper on "Foundations."

Business Meeting, December 21, 1907.—President Quimby in the chair. One hundred and six members and visitors present. No additional nominations for officers made.

The President announced the death of Mr. Wm. Wharton, Jr., active member, elected March 15, 1884, died November 26, 1907.

Mr. E. A. Sterling (Visitor), Forester of Pennsylvaina Railroad, read paper on "The Necessity for Corporation Forestry." The Secretary read a written discussion by Mr. A. E. Lehman.

The Tellers announced the election of John Anderson, Alfred L. Belfield, Richard L. Binder, William H. Boardman, M. M. Borden, H. N. Boureau, David F. Broderick, Edwin Clark, J. A. Colby, T. C. Craig, F. Thibault Cross, Fred E. Dolbier, Frank R. Fisher, Walter D. Gernet, William K. Gorham, Howard B. Green, Caspar Wistar Haines, Edw. C. Haldeman, Manton E. Hibbs, Edwin N. Johnson, Matthew L. Kyle, Wm. M. Laverty, W. T. Mansfield, Horace N. Manship, R. K. Matlock, J. T. J. Mellon, C. P. Mulherin, Howard Murphy, M. J. O'Meara, C. J. Parker, Wm. T. Pringle, Gilbert S. Smith, J. V. Stanford, George R. Stearns, S. M. Swaab, William H. Walters, James H. Williams, R. C. Williams, Jr., and Edward Woolman to active membership; that Howard Bain, J. S. Bradford, C. E. Chambers, John N. Costello, Wm. H. Gravell, Rexford A. Harrower, W. Y. Heaton, H. Hartley Hewitt, Edw. E. Krauss, Paul R. Loos, Thos. S. Martin, Wayne B. Morrell, Karl Nibecker, Chas. S. Redding, Frank H. Rogers, John I.

Rogers, Jr., Philip B. Sadtler, and R. N. Sargent were elected to junior membership; and that J. Frank Barber, J. Max Bernard, George M. Bridgman, Frank M. Campbell, Wm. J. Cooper, P. R. Foley, Charles E. McInnes, John Mustard, J. Herbert Schall, and Geo. F. Smith were elected to associate membership.

Business Meeting, January 4, 1908.—The first meeting of the Club in the new Club-house. President Quimby in the chair. One hundred and seventy-nine members and visitors present.

President announced the death of Dr. Coleman Sellers, who was elected an active member January 12, 1884, an honorary member May 4, 1901, died December 28, 1907.

Mr. F. B. Maltby (Visitor), formerly in charge of dredging work on the Panama Canal, read a paper on "Dredging Equipment of the Panama Canal."

Twenty-ninth Annual Meeting, January 18, 1907.—President Quimby in the chair. One hundred and thirty members and visitors present.

The Secretary announced that Samuel J. Dickey, H. D. Fisher, T. Bertram Genay, H. S. Murphy, Edward B. Myers. Joseph Upton, C. Clifford Wilson, and Howard M. Yeager had been advanced from junior to active membership.

The Secretary announced that in accordance with the By-Laws, S. Cameron Corson, S. S. Harper, S. J. Magarge, Jr., H. W. Reynolds, F. G. Rowbotham, B. J. Sullivan, and Samuel P. Yeo had been dropped from membership on account of non-payment of dues for the years 1906 and 1907.

The annual report of the Board of Directors for the year 1907 was duly approved.

The annual report of the Treasurer for the fiscal year of 1907 was duly approved.

President Quimby delivered the Annual Address, reviewing the history of the Club from its organization.

The Secretary announced the report of the Tellers on the election of officers, and the President declared the following elected: President, H. W. Spangler; Vice-President (two years), Washington Devereaux; Vice-President (three years), William Easby, Jr.; Secretary, Francis Head; Treasurer, Geo. T. Gwilliam; Director (one year), F. E. Dodge; Directors (two years), J. O. Clarke, H. G. Perring, Wm. S. Twining; Directors (three years), James Christie, H. P. Cochrane, Richard G. Develin, and Henry Hess.

The Secretary read the report of the Auditors, who certified to the accuracy of the report of the Treasurer for the fiscal year.

A vote of thanks was extended to the past officers and tellers of the Club.

Announcement was made of the death at Louisville, Ky., of Mr. Charles Hermany, Past President of the American Society of Civil Engineers.

Motion was made and approved that the thanks of the Club be tendered to Messrs. Dallett, Gwilliam, and Perring for services in connection with the "House Warming."

President-elect Spangler took the chair and made a short address.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, November 13, 1907.—President Quimby, Vice-President Dallett; Directors Dodge, Easby, Head, Loomis, and Perrot; the Treasurer and W. S. Twining of the Special Finance Committee were present. Mr. Head, Secretary pro tem.

The purpose of the meeting was to hear a report from Dr. Spangler, Chairman of the Special Finance Committee. This was in the form of a letter referring to new Club-house.

It was moved and carried that the House Committee be authorized to have the partition taken out of the second-story front room in order to make a larger meeting-room.

It was moved and carried that the House Committee be authorized to have fire-escape built per city requirements.

Regular Meeting, November 16, 1907.—President Quimby, Vice-Presidents Dallett and Devereaux; Directors Dodge, Easby, Head, and Loomis, the Treasurer and Secretary were present.

The Treasurer's report for the month of October was read and ordered filed, as follows:

Balance September 30, 1907		$4482.43
October Receipts		686.91
		$5169.34
October Disbursements:		
Current Expenses	$782.83	
New Club-house	1000.00	1782.83
Balance October 31, 1907		$3386.51

It was moved and carried that the Finance Committee be authorized to formulate plans for the term, denomination, and retirement of the second mortgage bonds, with power to act.

The resignations of Messrs. Henry G. Morris and Thos. J. Buckley accepted.

Upon motion it was decided that the invitation of the Atlantic Deeper Waterways Conference should be brought before the meeting of the Club later in the evening.

Special Meeting, November 22, 1907.—President Quimby, Vice-Presidents Dallett and Devereaux; Directors Dodge, Easby, Loomis, Ledoux, and Perrot, and the Treasurer and Secretary present.

It was moved and carried that the title insurance in the new Club-house be taken out with the Commonwealth Title Insurance and Trust Company.

It was moved and carried that the request of the Committee of Uniform Tests

of the American Society of Civil Engineers be permitted to use the Club-house for their meeting, December 6th.

It was moved and carried that the House Committee be authorized to contract with J. F. Buchanan & Co. to install the electric work and telephone wiring in the new Club-house, as per their letter of November 21st.

It was moved and carried that a special account be opened for the purchase and alterations of the new Club-house.

It was moved and carried that the House Committee be authorized to spend a sum not exceeding $6000 for furnishing and decorating new Club-house.

Special Meeting, December 2, 1907.—President Quimby, Vice-President Dallett, Treasurer Gwilliam and Directors Loomis, Ledoux, Dodge, and Head, who acted as Secretary pro tem., present.

It was moved and carried that the House Committee be authorized to build a cloak and toilet room in basement, new Club-house.

The terms for the second mortgage bonds were arranged at this meeting.

Special Meeting, December 7, 1907.—President Quimby; Vice-Presidents Dallett and Devereaux; Directors Dodge, Head, and Perrot, and Treasurer and Secretary present.

Proposal for the cloak room was submitted.

It was moved and carried that notice should be sent to the Girard Estate that the Club will vacate premises 1122 Girard Street, January 1, 1908.

Special Meeting, December 12, 1907.—President Quimby; Vice-Presidents Dallett and Devereaux; Directors Easby, Head, Loomis, and Perrot, and the Secretary were present.

Membership Committee discussion.

Regular Meeting, December 21, 1907.—President Quimby, Vice-Presidents Dallett and Devereaux; Directors Dodge, Easby, Head, Loomis, and Perrot, and Treasurer and Secretary present.

The Treasurer's report for November was accepted as follows:

Balance October 31, 1907		$3386.51
November receipts:		
Dues and Entrance Fees	$287.50	
Sale of U. S. Bond	511.25	798.85
November Disbursements:		$4185.26
Current Expenses	$596.84	
New Club-house	2000.00	2596.84
Balance November 30, 1907		$1588.42

It was moved and carried that the Thirtieth Anniversary of the founding of the Club be held January 11, 1908, in new Club-house.

It was moved and carried that the President and Treasurer be authorized to enter into contract with Philadelphia Electric Co. for electric lighting.

Meeting adjourned until December 26th, at the new Club-house.

Adjourned Meeting, December 26, 1907.—Adjourned from regular meeting of December 21st. President Quimby, Vice-Presidents Dallett and Devereaux; Directors Dodge, Easby, Head, Loomis, and Perrot, and the Treasurer and Secretary present.

The President announced Mr. Dallett and the Treasurer as the Committee on Publicity.

It was moved and carried that the Anniversary Meeting to be held January 11th, shall take the form of a reception. Messrs. Dallett and Gwilliam were appointed a Committee with power to add to their number.

Special Meeting, December 31, 1907.—President Quimby, Vice-Presidents Dallett and Devereaux; Directors Easby, Head, Loomis, and Perrot, and the Treasurer and Secretary were present.

Membership Committee submitted a report.

It was moved and carried that a Special Meeting of the Board of Directors be held January 4, 1908.

Special Meeting, January 4, 1908.—President Quimby, Vice-Presidents Dallett and Devereaux; Directors Dodge, Easby, Head, Loomis, and Perrot, and the Treasurer and Secretary present.

Special Meeting, January 8, 1908.—President Quimby, Vice-Presidents Dallett and Devereaux, Director Loomis and the Treasurer and Secretary present.

Informal work preparatory to Annual Report transacted.

Regular Meeting, January 18, 1908.—President Quimby, Vice-President Dallett, Directors Dodge, Easby, Head, Loomis, and Perrot, and the Treasurer and Secretary present.

The President appointed Messrs. Wilfred Lewis, James Christie, and Edwin F. Smith, Committee to prepare a memorial on the life and career of the late Dr. Coleman Sellers.

The Treasurer's report for the month of December was accepted as follows:

Balance November 30, 1907	$1588.42	
December Receipts	3488.80	
	$5077.22	
December Disbursements	1508.72	
Balance December 31, 1907		$3568.50
Bond Account:		
Receipts	$16,650.00	
Disbursements	13,675.56	2974.44
Total Cash Balance December 31, 1907		$6542.94

The annual report of the Treasurer for 1907 together with the certificate of the auditors was submitted to the Board.

Organization Meeting of Board of Directors, January 20, 1908.—President Spangler, Vice-Presidents Dallett and Easby, Directors Christie, Clarke, Cochrane, Develin, Dodge, Hess, Ledoux, Perring, Perrot, Quimby, and Twining, and the Treasurer and Secretary present.

Mr. Francis Head resigned as Secretary and Mr. H. G. Perring was elected to fill the vacancy. Mr. Perring resigned as a Director and Mr. Head was elected to fill the vacancy in the Board.

The President announced the following Standing Committees:

House: W. P. Dallett, Wm. S. Twining, James Christie, J. T. Loomis, and Henry Hess.

Meetings: Wm. S. Twining, J. O. Clarke, and Herman G. Develin.

Membership: Wm. Easby, Jr., J. O. Clarke, and H. P. Cochrane.

Finance: James Christie, F. E. Dodge, and J. W. Ledoux.

Publication: Henry H. Quimby, Richard G. Develin, and Francis Head.

Library: Washington Devereaux, F. E. Dodge, and H. P. Cochrane.

Publicity: Emile G. Perrot, George T. Gwilliam, and H. G. Perring.

Advertising: Geo. T. Gwilliam, H. G. Perring, and Henry H. Quimby.

The following members were elected Tellers for the ensuing year: Messrs. Nichols, Bradley, and Hubbard.

The following members were elected Alternate Tellers for the ensuing year: Messrs. Edwin M. Evans, Alan Corson, and Moriz Bernstein.

The following members were elected Auditors for ensuing year: Messrs. W. B. Riegner, H. E. Ehlers, and H. T. Grantham.

The death of Mr. Geo. V. Cresson, active member, was announced and the Chair appointed a Committee to prepare a memorial.

It was moved and carried that the renting of the sleepings rooms be placed in charge of the House Committee.

The House Committee was requested to make a report on establishing a restaurant in the Club-house.

THE ENGINEERS' CLUB OF PHILADELPHIA,

House, No. 1317 Spruce Street,
PHILADELPHIA, PA.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

For the Fiscal Year 1907

JANUARY 8, 1908.

TO THE MEMBERS OF THE ENGINEERS' CLUB OF PHILADELPHIA:

The Board of Directors hereby presents its report for the year ending December 31, 1907:

Eighteen regular meetings and one special meeting of the Club were held, at which the maximum attendance was 137 and the average 86, an increase in average attendance of 7 members. Nine stated, five adjourned, and sixteen special meetings of the Board of Directors were held.

Ninety-two active, 32 junior, and 19 associate members were elected; 36 active, one junior, and one associate member resigned; six active members and one associate member were dropped from the rolls; and eight junior members were advanced to the active list.

The record of deaths is:

Wm. H. Derbyshire, Active Member, died April 13, 1907.
Pat. Doyle, Active Member, died March 27, 1907.
Willis L. Essen, Junior Member, died May 8, 1907.
Chas. H. Haswell, Honorary Member, died May 12, 1907.
Thos. A. Roberts, Active Member, died February 11, 1907.
Coleman Sellers, Honorary Member, died March 23, 1907.
J. P. Webster, Active Member, died March 23, 1907.
Wm. Wharton, Jr., Active Member, died November 26, 1907.

	1906.			1907.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total.*
Honorary	2	4	6	1	3	4
Active	347	117	464	414	104	518
Junior	19	6	25	38	9	47
Associate	24	...	24	40	...	40
	392	127	519	493	116	609

The following papers have been presented:

JANUARY 5th.	Power Plant of the Ontario Power Plant Co. at Niagara Falls, Ont.	William M. White.
JANUARY 19th.	Address of Retiring President. Recent Development in Large Central Electric Plants.	Thos. C. McBride.
FEBRUARY 2d.	Single Phase Railways.	F. E. Wynne
FEBRUARY 19th.	Hydraulic Gold Mining in British North America.	H. W. Du Bois.
MARCH 2d.	Discussion of paper—Recent Development in Large Central Electric Plants.	

MARCH 16th.	Modern Timber Preservation.	Gellert Alleman.
APRIL 6th.	Electrical Plant and Means of Interior Communication of a Modern Ocean Going Passenger and Cargo Vessel.	Chas. J. Dougherty.
APRIL 20th.	Some Observations on the Physical Properties of Cast Iron.	James Christie.
MAY 4th.	Notes on Gas Power Plant Practice; Operating Results and Equipment.	J. R. Bibbins.
MAY 18th.	Modern Glaciers: Their Movements and the Methods of Observing Them.	W. S. Vaux.
JUNE 1st.	Ball and Roller Bearings in Practical Operation.	S. S. Eveland.
SEPTEMBER 21st.	Illustrated Talk on a Recent Visit to the Quebec Bridge.	Silas G. Comfort.
OOTCBER 5th.	Club Smoker. Informal Talk on Walnut Lane Bridge.	Henry H. Quimby.
OCTOBER 19th.	Business Meeting. Discussion of New Club House.	
NOVEMBER 2d.	New Regulations of the Bureau of Bldg. Inspection of the City of Philadelphia in regard to the use of Reinforced Concrete.	Emile G. Perrot.
NOVEMBER 16th.	The Helion Lamp.	H. C. Parker.
DECEMBER 7th.	Foundations.	A. B. Clark.
DECEMBER 21st.	Necessity for Corporation Forestry.	E. A. Sterling.

The following books were added to the Library during the year 1907:

The Black Trail of Anthracite.
The Engineering Index, 1906.
Thorp's Industrial Chemistry.
Clark's Mechanical Engineering Formulæ.
Clark's Architect, Builder and Owner before the Law.

When negotiations were opened for the purchase of a new Club House, it was deemed advisable by the Library Committee not to purchase any more books except upon special written request of the members. A full index of the library can be found in the Club Directory for 1907.

The value of the library is two thousand dollars ($2000).

The important event of the year was the purchase by the Club of the property No. 1317 Spruce Street, with the cancellation of the lease of the property No. 1122 Girard Street, and the removal of the Club's quarters to the new house.

The purchase price of the new property was $55,000. The alterations and furnishing have not been quite completed, but it is known that the total cost, including fees, and insurance, and interest, and the expenses of issuing the mortgage bonds will be less than $15,000, so that the total cost of acquiring and fitting up the new quarters will be not over $70,000.

The payment of the purchase price consisted of $15,000 cash and a first mortgage for $40,000 maturing in five years. The first two payments, $1000 and $2000 respectively, were made out of the Club's treasury. Provision for the balance of the purchase money and the cost of alterations and furnishing was made by the issue of bond scrip preliminary to the issue of second mortgage bonds to bear interest at the rate of five per cent. per annum from January 1, 1908, the issue being limited to $30,000; to secure which a second mortgage for $30,000

has been executed in favor of the Colonial Trust Company, which company certifies the bonds. This mortgage with the $40,000 first mortgage provides the $70,000 required.

The subscriptions to the bonds to date amount to $25,750 from 94 members. Of this amount $16,650 has been paid in and bond scrip issued therefor. In order to meet maturing bills the balance of the subscriptions should be paid in at once, and in order to reimburse the Club's treasury for payments on the property account, it is desirable that the balance of the bond issue should be subscribed for at an early date.

A statement is herewith submitted of the net expenditures for the year; also a comparative statement of the assets and liabilities at the beginning and end of the year. The increase in the expenditures over those for 1906 is due largely to the higher cost of the Proceedings and the expenses incidental to the increased membership, and the acquisition of new property.

NET EXPENDITURES FOR 1907.

House	$2937.07
Library	105.13
Proceedings and Directory	883.61
Information	141.32
Office	1047.92
Salaries	1735.00
	$6850.05

ASSETS.

	Jan. 1st, 1907.	Dec. 31, 1907.
Furniture and fixtures, as per appraisement	$1,750.00	$1,000.00
Library, as per appraisement	2,000.00	2,000.00
U. S. Bond, issue of 1898 (par $500), market value	513.75	
On deposit, bearing interest at 3 per cent	2,143.92	208.46
On deposit, bearing interest at 2 per cent. (including advance dues)	1,779.75	6,334.48
Outstanding dues considered good and collectable (being dues for the years 1906 and 1907 respectively remaining unpaid on the 31st of December by members in good standing)	350.00	565.00
Expended on purchase of property, 1317 Spruce St.		56,675.56
Outstanding bills for Directory advertisements		30.00
Outstanding bills for Proceedings advertisements		108.00
	$8,537.42	$66,921.50

LIABILITIES.

Advance dues collected and included in above bank deposits (being dues for 1907 and 1908 respectively)	$510.00	$1,726.25
First mortgage on property, 1317 Spruce Street		40,000.00
Amount collected from sale of second mortgage bonds		16,650.00
	$510.00	$58,376.25
Net Assets	$8,027.42	$8,545.25

Respectfully submitted,

Henry H. Quimby, *President.*

Walter Loring Webb, *Secretary.*

REPORT OF THE TREASURER FOR THE FISCAL YEAR 1907.

Receipts.

Initiation Fees (143)	$715.00	
1892 dues	15.00	
1893 dues	10.00	
1894 dues	15.00	
1895 dues	30.00	
1896 dues	15.00	
1906 dues	265.00	
1907 dues	6,062.50	
1908 dues	1,726.25	$8,853.75
Proceedings:		
Advertisements	237.00	
Sales	99.00	
Reprints	99.30	435.30
House:		
Telephone	16.10	
Billiards	5.40	21.50
Slides		11.60
1907 Directory		937.00
Interest on Deposit		114.91
Interest on Investment		15.00
Sale of U. S. Bond		511.25
		$10,900.31
Received from Sale of 2d Mortgage Bonds		16,650.00
Total Receipts		$27,550.31
CASH BALANCE, DEC. 31, 1906,		**3,923.67**
		$31,473.98

Expenditures.

Salaries:		
Secretary	$360.00	
Treasurer	175.00	
Clerk	600.00	
Janitor	600.00	$1,735.00
House:		
Rent	1,260.00	
Coal	215.75	
Gas and Electric Light	132.08	
Ice	29.83	
Supplies and Repairs	420.21	
Telephone	244.20	
Insurance	13.50	
Luncheons	643.00	2,958.57
Office Expenses		1,047.92
Proceedings		1,750.55
Information Committee		152.95
Library Committee		105.13
1907 Directory		505.36
		$8,255.48
Expended on Property Account		16,675.56
Total Disbursements		$24,931.04
CASH BALANCE, DEC. 31, 1907,		**6,542.94**
		$31,473.98

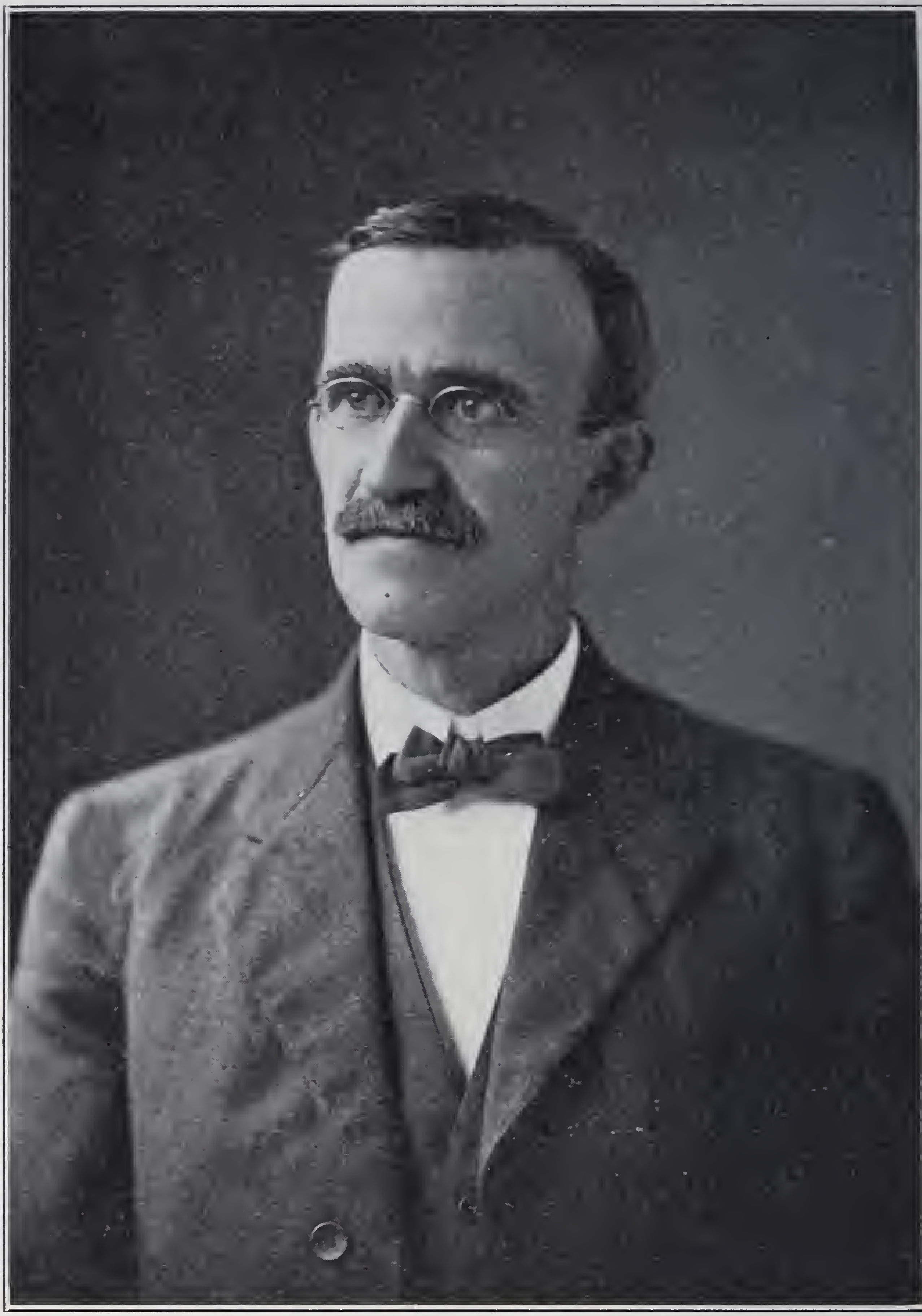
Respectfully submitted,
GEO. T. GWILLIAM, *Treasurer.*

PHILADELPHIA, January 4, 1908.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks, and bank-books, and found them to correspond with the Treasurer's statement submitted above.

H. W. SPANGLER }
W. B. RIEGNER } *Auditors*

January 14, 1908.



Henry H. Quimby

Thirtieth President of the Club. Jan. 19, 1907–Jan. 18, 1908.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXV. APRIL, 1908. No. 2

PRESIDENT'S ADDRESS.

HENRY H. QUIMBY.

Annual Meeting, January 18, 1908.

Our Club, at the close of the third decade of its career, is apparently entering upon a new epoch in its history, with expanded ideas and higher ideals, and with increased facilities for social enjoyment, and for usefulness to its members and the profession of engineering and the community.

The combination of the two events of such immediate interest makes the time seem opportune for a familiar personal discussion of Club affairs, with a glance back over the record that we have made, rather than for the conventional survey of the engineering field with its compilation of the engineering progress and events of the year, or for a formal technical paper on a special subject.

It is only in old age, however, that one's principal occupation is a retrospective one—living in the memories of the past. At thirty a man is only entering upon the period of his greatest capacity for sustained and successful effort—the most prolific and productive period of his life—and this period should cover another thirty years—so our look back over the past will be merely for refreshment and for inspiration for the activities of the coming year.

The history of the Club has been written and brought up to the year 1905. It is in accessible and permanent form in our "Proceedings"—spread out in the minutes recorded by the first Secretary, Chas. E. Billin,

—still a member, though resident in Chicago—and by his successors. It is in condensed form in the "Proceedings" in the historical anniversary address by Professor Marburg in 1900, and the after-dinner speech at the banquet of the Club in 1901, of Mr. Wilfred Lewis, one of the only two survivors of the original number that are still resident members, and in the address of Mr. Carl Hering, delivered at the time of his retirement from the office of president in 1905.

Organized by the election of officers December 17, 1877, constitution and by-laws discussed January 8, and adopted January 19, 1878,—just thirty years ago,—the Club was born of the happy thought of a few wide-awake and ambitious young engineers—perhaps suggested, or at least encouraged, by the acquaintances made during and following the Centennial Exposition in the previous year, when many engineers from abroad visited the city.

It is not at all improbable that the organization was a sequel of the career of the Engineers' Essay Club of Fairmount Park, of which Professor Haupt was the organizer and an active member; and as he became the first president of our Club, a connection between the two may be regarded as established. Our Mr. J. Kay Little, who was one of its members, furnishes the information that the Engineers' Essay Club was composed of twenty-five or thirty members—the whole of the Fairmount Park Engineer Corps of that day—and was organized in 1869 and continued in active existence until the disbanding of the corps in 1872 scattered the members and many of them departed to other fields of professional labor. In its membership, besides Professor Haupt and Mr. Little, were Rudolph Hering, Joseph Johnson, and Frederick L. Paddock, present active members of our Club, and Samuel L. Smedley and Preston C. F. West, formerly members, now deceased. Its objects and methods were similar to ours, with the very important difference in methods, however, as Mr. Little says, that after meeting collations were not served.

The original membership of our Club is said to have numbered twenty-one, though eighteen is recorded as the number attending the organization meeting. It grew until the autumn of 1878, when it reached the originally established limit of fifty. It then acquired a waiting-list—an appendage that seems to be regarded as a valuable asset of a club, and is one that we may before long be in a position to consider establishing again.

Then came a reorganization, attended by an increase of the dues,

and this resulted in increased membership and attendance. In January, 1879, the publication of the "Proceedings" was commenced, and, as quoted in Professor Marburg's historical sketch, the "Engineering News" greeted the first number with the comment that it was "the most creditable display of enterprise ever exhibited by any American engineering society."

The membership increased, and more commodious quarters were sought. The early meetings were held at the residences of various members, the one at which the organization was effected having been held at 3301 Baring Street, the home of Coleman Sellers, Jr., whose father, Coleman Sellers, joined the Club later, and subsequently became an honorary member and died only a few days ago. In April, 1878, it rented and occupied the third floor of No. 10 North Merrick Street, now North Broad Street, the site of the Pennsylvania Railroad Broad Street Station. In September, 1879, the Club moved to 1518 Chestnut Street; in December, 1881, to 1523 Chestnut Street; and in October, 1885, to 1122 Girard Street, the house that we have just abandoned after twenty-two years of occupancy.

In June, 1892, the Club was incorporated and empowered by the court to hold and transfer real estate and personal property, the real estate limited to a yearly income value of $20,000.

The objects of the Club as expressed in its original constitution were essentially the same as stated in our present charter, "the professional improvement of its members, the encouragement of social intercourse among men of practical science, and the advancement of engineering in its several branches."

A disposition to enhance the market value of engineering talent by controlling the supply of practitioners was evidenced at the first meeting, when a member proposed the restriction of the number of practising engineers by suppressing, in some way not stated, any ambitious young man who might desire to enter the profession. To the everlasting credit of the meeting and the profession, the proposer of that scheme seems to have come near being himself suppressed.

The yearly dues were originally $5.00. In 1880 they were increased to $7.50; in 1890 to $10.00, and in 1893 to $15.00, at which figure they continued for fifteen years until the recent advance to $25.00 for 1908.

In its early days the Club appears to have felt, or at least displayed, more interest in public questions than it has done in recent years. It

memorialized Congress and the Pennsylvania Legislature on several occasions in the interest of measures then before those bodies. The establishment of the metric system standard of weights and measures; provision for testing materials of construction; and a geodetic survey of the State, were subjects that brought the Club into such action.

Receptions were tendered to engineering societies holding conventions in this city, and to notable visiting engineers, such as Ferdinand de Lesseps, in 1880, and the French delegates to the World's Fair, in 1903.

The scientific activities of the Club were, from the beginning, varied, energetic, and profitable. Topics were numerous and discussion spirited. Many short papers were presented, notes of interesting works and discoveries were frequently contributed—almost always by members and often by officers, instead of largely by visitors as is the case in these days.

Apparently the social element of society life was not uppermost in the thoughts of the organizers of the Club. The records indicate that the advancement of the science of constructive engineering was the principal object of their effort, and after reading the Club's history and seeing the list of timely, important, and valuable papers that were presented and discussed, one can have no doubt of its accomplishment. But early addresses show that the advantages of a greater degree of intimacy of social as well as professional intercourse than was then enjoyed were recognized and striven for.

One of the primitive efforts to promote sociability and increase the attendance at the meetings has been a matter of tradition heretofore —not recorded history. This was an experimental investment, through private subscription, in sandwiches, pretzels, and bottled beer—two bottles per capita, repeated at a number of meetings. It is said by a survivor of the syndicate that one of the members was a total abstainer from beer, and for him special provision was made in the shape of a generous measure of plain whisky. Apparently the few became tired of bearing the expense for the benefit of the many and suspended the practice.

Such stimulating gastronomic accessories to scientific purpose, or, more correctly, such gastronomic stimulants, were later officially ordained and provided, but it is orally handed down that they led to disquieting and disturbing conditions, and they were then and—permit me to express my personal hope—permanently, abandoned.

The general plan of enlisting the palate in the promotion of good fellowship, with the ultimate view of advancing intellectual pursuit,

is clearly wise, if under prudent and restrictive government, because it is proved effective and is not wrong in principle, but the details of the plan are as vitally important to success as they are in all constructive effort. So it took several trials to adjust the physical refreshment to the mental pabulum, and, as should always be the result when engineers take hold of a project, the purpose has been and is being accomplished by our present methods. The luncheons after the regular meetings may or may not attract members, but they certainly keep them here in enjoyable converse and profitable acquaintance.

Thus our plans mature, our ideas crystallize, our methods improve. We are advancing along the line that constantly approaches perfection yet never reaches it. We are striving after not so much perfection as excellence—a higher degree of excellence—in our work, and at the same time more complete and rational enjoyment of life.

A very thorough analysis of the Club's experience—its ups and downs in progress and the causes of them—was made by Mr. Carl Hering in his presidential address in January, 1905, published in the "Proceedings" of that time. It is a most thoughtful and comprehensive review of the Club's career; a painstaking study of the development and work of the Club. He employs the engineer's instrument—the curve sheet diagram —to graphically exhibit the mutations in growth and activity and resources, and he deduces lessons from the experience, and discusses various policies of management.

Since Mr. Hering's record was filed the Club's progress has been steady and real though uneventful until within a few months just past, when events crowded us somewhat.

In 1905 the total number of members of all classes became 499, an increase nominally of 3 over the previous year, but actually of 17; because, of the 31 resignations that year 14 were as of the year 1904. The average attendance at meetings rose to 97—the high-water mark—one of the meetings, which was held in Witherspoon Hall when the paper on the Torresdale Conduit was read by Mr. John W. Hill, showing an attendance of 303. During that year 1 honorary member, Gen. Herman Haupt, and 9 active members died; 7 were dropped, and 51 new members were elected. Twenty-two papers were presented. An excursion was made to and through the then completed portion of the Market Street subway. An interesting exhibit of new engineering appliances was held in the Club-house on the evening of the annual

meeting. A substantial net increase in the Club's treasury was shown by the annual report. Altogether, the year was an active and profitable one.

The year 1906 also shows a marked advance in membership and financial assets, though the average attendance fell off somewhat to 79. New members numbered 45; 16 members resigned; 4 were dropped and 8 active members died; the total number at the end of the year being 519. Sixteen papers were presented—the low-water mark in the Club's history—two of the eighteen meetings having been devoted to discussion of more than ordinarily important papers. The yearly visit of the Club was to the new engineering building of the University of Pennsylvania, where the regular meeting of November 3d was held, and a thorough inspection was made of the extensive and admirable equipment. A valuable and notable addition to the Club's library was made by the purchase of a set of the new International Cyclopædia and a set of the Americana.

During the year the project of establishing a restaurant or café was agitated, and a committee was appointed to consider the subject. The possibilities of the cellar of the house for conversion into a suitable room for the purpose were investigated, and the situation was regarded as unpromising, for considerable outlay would be required for alterations, with little prospect of making the place attractive.

The year 1907 was also not very prolific of scientific papers, possibly because of the earnest attention given throughout the year to the efforts to secure a new club-house. Only sixteen papers were read—the same number as in the previous year—one of the eighteen regular meetings being devoted entirely to discussion of Mr. McBride's paper on Large Central Electric Plants, which constituted his presidential address, and another regular meeting being given up wholly to debate of the proposition to purchase the Spruce Street property, and of the proposed amendments to the by-laws.

The annual excursion was made to the Walnut Lane bridge over the Wissahickon.

A committee of members of the Club had been appointed in October, 1905, in response to a request by Mr. Edwin Clark, Chief of the Philadelphia Bureau of Building Inspection, to consider and recommend specific regulations to govern the use of reinforced concrete in buildings. As the fruit of many meetings, a code of rules was formulated during the

past year, and it was adopted and promulgated by the Director of the Department of Public Safety, and incorporated with the city building laws. The result of the committee's labors was presented to the Club at its meeting on November 2d, by Mr. E. G. Perrot, chairman, in the shape of a paper analyzing and discussing the various features of this important accomplishment.

Without having had any phenomenally large meeting during the year, the average attendance at meetings was 86. The membership roll shows a large increase, 143 of all classes having been elected—most of them after the new Club-house project had matured. 38 resigned, 7 were dropped, and 8 died—two of the latter being honorary members, Charles H. Haswell and Coleman Sellers. The net increase in membership was 90—over 17 per cent. It may be of interest to note that of the resignations, the whole number of which is but little greater than in former years, very few are attributable to the move made in changing to the new Club-house and increasing the dues.

The culminating event of the year's activities was the acquisition of the new Club-house, with the assumption of the responsibilities of ownership and its attendant dignity, and the development of the policy and purpose of the Club. It is the fruit of persistent and determined effort, encouraged by confidence in the spirit and ambition of the membership.

The desire for more modern appointments and greater conveniences made itself felt in the Club a decade ago, and spasmodic attempts to launch out are recorded in the minutes of the Club meetings and of the Board meetings.

The chronology of the movement as abstracted from the records is as follows:

March 6, 1897, Club Minutes: Resolved that a committee of five members be appointed to deal with the subject of a new Club-house.

March 8, 1897: Committee appointed: A. Falkenau, Chairman, W. C. Furber, John C. Trautwine, Jr., Henry Leffmann, and Carl Hering.

March 20, 1897, Club Minutes, Board Minutes: Committee increased to eight members. Offers of Lawyers' Club, Manufacturers' Club, and Mr. Samuel Levis referred to Committee on new Club-house.

April 24, 1897, Board Minutes: Question of erecting a fifteen-story office building 1416-18 South Penn Square, total cost $339,380, total annual expenses $26,250, and total annual income $52,000, referred to Committee.

June 18, 1897, Board Minutes: Franklin Institute, Geographical Society, and others had been conferred with in regard to a joint building, locality

Arch to Spruce and Twelfth to Sixteenth, cost $650,000—matter left in the hands of the Committee to arrange details, building to be under a general name, each society to have its separate quarters.

October 8 ,1897: Call for a meeting sent to Falkenau, Richards, Leffmann, Trautwine, Furber, Hering, and Schermerhorn.

October 29, 1907: Call for a meeting sent to Falkenau, Richards, Furber, Schermerhorn. Trautwine, Hering, Marburg, Christie, and Leffmann.

November 20, 1897, Board Minutes: Information Committee requested to set a date for the report of the Committee to the Club.

November 23, 1897: Sub-committee appointed to make a report to the main Committee on any work done so far, as follows: Leffmann, Schermerhorn, and Furber.

December 18, 1897, Club Minutes: General discussion opened by the presentation of the report of the Committee, which ended with a resolution to the Board directing further investigation of probable costs of different projects, and possible increase of revenues.

January 15, 1898, Board Minutes: Action by the Board upon the resolution presented to the Club on December 18th was postponed.

February 19, 1898, Board Minutes: Matters postponed at the previous meeting of the Board were referred to the Committee with a request for a report at the April meeting.

April 16, 1898, Board Minutes: Committee reported that they had not the necessary data for a report at present.

January 30, 1899: Committee re-appointed—Furber, Chairman, Falkenau, Hering, Marburg, Christie, Leffmann, and Trautwine.

May 20, 1899, Club Minutes: Wm. H. Webster appointed to take the place of Dr. Leffmann, resigned. Mr. Webster subsequently withdrew, and Dr. Leffmann's name was kept on.

January 27, 1900, Board Minutes: Committee asked by the Board for a report at its early convenience.

February 17, 1900, Board Minutes: Committee reported, through its chairman, that a meeting would shortly be called.

January 26, 1901, Board Minutes: Committee requested by the Board to report on February 16th.

Feburary 1, 1901: Resignation of Dr. Leffmann. Appointment of Mr. Bonner.

February 15, 1902, Board Minutes: Committee authorized by Board to appoint two members to confer with Dr. Gertrude A. Walker on a new Club-house.

January 21, 1903, Board Minutes: Letter read from Mr. Dodge reporting progress.

January 23, 1904, Board Minutes: Estimate of $500 cost of building a brick addition to the rear room, first floor. Estimate ordered for addition covering first and second floors.

February 6, 1904, Board Minutes: Proposed to rent rooms in Witherspoon Building. Estimate of cost of fitting up basement lunch room, $235.

Club Minutes: President announced that a special meeting will be called to consider the change in location of the Club-house.

February 20, 1904, Board Minutes: Mr. Loomis presented an estimate of $1200

for a two-story brick addition to Club-house; also an estimate for $250 for steam heat.

January 21, 1905, Board Minutes: Chairman J. M. Dodge reported progress on new Club-house question.

June 2, 1906, Club Minutes: Motion made that the Board should prepare plans for alterations in the Club-house. Motion ruled out of order, to be brought up at September meeting.

July 2, 1906, Board Minutes: Report from House Committee regarding establishing a restaurant in the Club-house. Report not favorable and matter dropped.

October 6, 1906, Club Minutes: Report of the House Committee to the Board read, on the question of establishing a restaurant. Motion that a restaurant be established in the Club-house to be brought up at next business meeting.

October 20, 1906, Club Minutes: Committee of five members appointed to consider the question of having lunch in the Club, and also the question of converting the basement into a lunch room.

November 3, 1906, Club Minutes: Committee appointed, Perrot, Chairman, Perring, Loomis, Gwilliam, and Dallett.

February 11, 1907, Board Minutes: President, Treasurer, and Chairman House Committee be authorized to secure option on property at Camac Street and St. James, or 333 to 335 South Thirteenth Street, price not to exceed $25,000.

June 24, 1907, Board Minutes: Consideration of the proposition to lease or purchase 1317 Spruce Street. Call ordered sent out for Special Meeting of Club on July 1st.

June 26, 1907, Board Minutes: Discussion of proposed lease of 1317 Spruce Street. Statement of the financial aspect to be drawn up.

July 1, 1907, Club Minutes: Special Meeting of Club. Motion passed directing the Board to execute the lease of 1317 Spruce Street, for three years, at $4000 per annum, and advocating amendment to by-laws increasing dues.

August 16, 1907, Board Minutes: Report made that owner refused to execute the lease to 1317 Spruce Street. Statement ordered sent out to members regarding the negotiations.

September 10, 1907, Board Minutes: Meeting of Board and Past-Presidents. Three Committees appointed: (1) to continue the search for a desirable property; (2) to confer with Franklin Institute; (3) to canvass the membership on the question of subscribing for bonds.

September 18, 1907, Board Minutes: Report that the property at Camac and St. James had been sold. Following Committees appointed: (1) Gwilliam, Dallett, Havens, Loomis, Perrot; (2) Marburg, Christie, Webster, Quimby, Easby; (3) Spangler, Dallett, Gwilliam, Lober, Twining.

September 21, 1907, Club Minutes: Proposed Amendments to the by-laws presented.

October 11, 1907, Board Minutes: Committee reported agreement with owner and payment of $1000 on account of property (1317 Spruce Street).

October 15, 1907, Board Minutes: Letter sent to members giving statement of cost of purchasing, altering, and furnishing 1317 Spruce Street.

October 19, 1907, Club Minutes: Board authorized to complete the purchase of 1317 Spruce Street, and to issue bonds to complete the purchase and to provide money for altering and furnishing the house.

November 2, 1907, Club Minutes: Amendments to the by-laws carried.

November 16, 1907: Second payment of purchase money made—$2000.

December 27, 1907: Balance of purchase money paid, first mortgage executed, title transferred to Club.

December 31, 1907: Old Club-house vacated; furniture, etc., moved to new.

December 21, 1907, Club Minutes: President announced that the next meeting of the Club would be held at the new Club-house.

January 4, 1908, Club Minutes: First meeting held in the new Club-house.

The agitation in the fall of 1906 of the question of establishing a restaurant in the house on Girard Street, though it failed in its immediate purpose, may have stimulated the determination early in 1907 to accomplish something definite in the direction of ampler accommodations. The fact should be recorded in the annals of the Club that most active and energetic in the long-continued pursuit of this object was Treasurer George T. Gwilliam, who early in the year announced his purpose to retire from office at the end of the term, and his ambition to see something definite accomplished before that. His recent acceptance of office for another term—his fourteenth—merely shows that a wise man may be persuaded to change his resolution when his duty is made clear to him.

The search of real estate offices for either an available building lot or a suitable house ready built brought upon us much visiting and inspection of properties. At one time the most attractive proposition was a lot of ground at the corner of two back streets in a somewhat unsavory neighborhood, that was, however, undoubtedly destined to be improved in the near future. Five small old dwellings occupied the ground, but they were all rented and producing considerable revenue. We were led to expect that we could purchase the property for $20,000 and were so confident of its rapid appreciation that we felt justified in securing it if possible, and the Board therefore authorized the agreement of purchase at a price not exceeding $25,000 and the payment of earnest money not exceeding $500.

Mr. Perrot designed a building to occupy the whole lot and anticipation was high. However, before our committee could secure the option the property was purchased by another club at $25,000. The

location was hardly more convenient than that of the property we have secured, and the size was very much less.

The Potts mansion, 1317 Spruce Street, was first inspected by Mr. Gwilliam upon having his attention drawn to it by real estate broker Frederick Sylvester, whom he had consulted as to available properties, and he immediately recognized its adaptability and announced by 'phone that he had found a "cracker-jack house." This judgment was approved by his colleagues at the first visit and negotiations were at once opened and terms of lease for three years, with option of purchase at $70,000, were arranged with the owner's agent. The terms were submitted to the Club at a special meeting, July 1, 1907, and after debate were approved. The lease was drawn and forwarded for signature to the owner, who was then traveling in Europe, but the owner declined to execute the lease and declared the deal off.

The search for a property was renewed with vigor, and prosecuted with weary feet, determination growing as prospects dwindled. Many houses were offered and inspected and dismissed. One we visited often and hesitated long over, always returning in mind to the Potts house.

Eventually the owner returned. We commissioned agent Sylvester to reopen negotiations, and after offer and counter-offer; offer adhered to and counter-offer lowered; after an unyielding maintenance of our first position our offer of $55,000 was accepted and $1000 earnest money paid down.

The Board's action was submitted to the Club at the regular meeting on October 19th, and approved. In anticipation of success in securing a house and in order to accomplish the necessary change in the by-laws to increase the dues for 1908 to meet the prospective increase of expense, amendments were proposed in time for debate at the same meeting and were passed to letter ballot.

The adoption of the amendments by the ballot canvassed November 2d completed the necessary confirmatory action of the Club, and the purchase was accordingly consummated and the title was transferred December 27, 1907.

The substantial unanimity of sentiment expressed in the debates was extremely gratifying to the Board, and justified all the exertions of the sponsors of the project.

After much discussion of aims and purposes during a period of ten years; after many conferences and delays; after reconciling divergent views as to what we really wanted, the problem was solved by

simply doing. It may be that what we have done is not the best and wisest, but it is what the great majority desired. In a company of many minds it cannot be expected that there will be entire unanimity of feeling in respect to questions of either policy or taste. So in our Club there may be some individual preferences that are not met, some tastes that are not gratified, but there has been no factious opposition. We can never have everything quite as we would like it to be, either in our business or in our homes or in our politics, and the philosopher's virtues are of use to us everywhere.

In the discussions of our Club development there were two distinct but not necessarily conflicting ideas of its destiny—the scientific and the social. It has been held and said that we cannot develop normally in both lines—that only one can be successfully pursued—that we can cultivate social club life only at the sacrifice of professional advantages. Whether this theory is correct remains to be demonstrated. It may very well be that the attractions of congenial social diversions by inducing the congregation here of a larger number of the members will stimulate at least discussion if not production of papers. We are in for a trial of it, we are established here under very encouraging and auspicious conditions, and we see reason to hope that we shall succeed.

The fruit of the past year's tilling is ripe and we have commenced to gather it. The taste of it we find to be good, and, wisely partaken of, it is nourishing and strengthening. Conditions of life are constantly changing, and our tastes and inclinations change with them. We secure comfort and peace by keeping in reasonable accord with the general course of events. Let us make use of the opportunities we have now to enjoy ourselves and improve ourselves, and increase our powers for productive effort, and extend our capacity for intellectual enjoyment, and thus augment the sum of our happiness in life.

The measure of one's success in life is the extent of the accomplishment of his desires. Morally the measure is the amount of happiness of his fellow-beings that he is instrumental in promoting, but actually he only promotes others' good as he enjoys doing it, for in the last analysis we do what we like best to do and get the most pleasure out of. The logical deduction from this is that there is no such thing as doing good for its own sake—if we resist temptation it is only because we prefer to abstain, whether it be through fear of consequences or in hope of reward. Our conduct, our aims, our work, and our recreations, all are matters

of taste—but, of course, taste, like a vegetable, can be cultivated and measurably modified by environment and effort.

Our Club is now taking a higher rank in the social scale with the added dignity and honor that are accorded to means and strength as indicated by display, and we must maintain our position. To do this the membership must be kept up for revenue—luxuries and display require means to maintain—and standing and importance in a community impose obligation to maintain dignity. The interest in the meetings and the papers must also be kept up by earnest effort to keep in the front rank of professional endeavor. Success in any line—social, professional or commercial—will depend upon the free resort of the members to the Club-house, and scientific growth will, in addition, depend upon the production and discussion of original technical papers.

At the risk of inviting the charge of tiresome reiteration, the subject of the presentation of original papers by the members of the Club is thus dwelt upon again. Our dependence upon visitors for the bulk of our professional entertainment will inevitably reduce our meetings to a less interesting and profitable plane through the acceptance of articles already published, and through the enervating force of mere inactivity. To prosper as a society of engineers we must strive to be the medium of giving to the profession new and good thoughts and ideas. Papers to be valuable need not necessarily be long and formal. A brief suggestion may bring out a profitable discussion.

There should be more than one subject in an evening, time for discussion being obtained by printing and circulating the papers in advance and reading them only in abstract at the meeting. The discussion is always stimulated by the hearing, and by the opportunity to speak at the moment, rather than by reading and then having to write the discussion.

Mr. Maignen has suggested the institution of a question box. If used, and the questions promptly referred and answered, it would undoubtedly work up a good measure of lively and profitable interest.

Also members might send in suggestions of subjects for topical discussions, or names of available authors.

The fact that the reception and publication of the paper describing a successful new method, or an effective appliance, may advertise and promote the commercial advantage of the author is not necessarily a reason for barring the paper out. At the same time our "Proceedings"

should not be used to exploit untried schemes, though the meetings furnish a ready and proper means of measuring the value of innovations.

The younger element of the membership should be ambitious enough, and not too diffident, to furnish voluntarily so much original matter that the meetings committee will not need to solicit it. The material advantages—the commercial profit—must needs be far more largely to the young and undeveloped than to the older and well-established engineers. Some systematic effort to utilize, to bring out the talent that our junior and younger active members undoubtedly have should be made.

The field of endeavor is not narrowing, but widening. The demands of advancing civilization open new and greater avenues for improvement, and they also require better and more thorough equipment for the work, and the young engineer will acquire such equipment not alone by study of text-books, but by contact with successful fellow-workers and discussion of their methods.

Nature develops only in response to demands; the evolution of types proceeds along lines of maintained activity. So the science of constructive engineering continues to meet demands as they arise, and the profession expands accordingly.

The plea just made for several subjects in an evening suggests the thought that one should not confine his attention to the special branch in which he is immediately engaged. The modern tendency to specialization may lead to narrowness. A fair knowledge of the general science adds to the equipment for special work. One of the most valuable qualities that an engineer can possess is adaptability, because he is subject to demands upon him that require knowledge beyond any one specialty, and, besides, it seems that a mind fitted to develop engineering mastery in any branch must feel more or less interest in all scientific problems.

One of our Club's strongest and most creditable features and one that should be carefully guarded and cherished is our "Proceedings." The second annual report of the Board of Directors, made in 1880, says "that to which we owe our greatest success and standing at home and abroad has been, as heretofore, our publication."

The volumes of the "Proceedings" to date constitute a valuable library of interesting and profitable engineering literature, the back numbers being especially rich, and I recommend to all our new members that they take up the perusal of them. In anticipation of this function

and in preparation for it I read all the annual addresses of my predecessors—twenty-nine in number. I entered upon this reading as a duty and pursued it in delight. The addresses form a library in themselves—rich in record of great accomplishments, and eloquent in wise counsels, and so much so as to be discouraging to the tyro who finds himself facing the necessity of trying to measure up with them. Every variety of dignified and scholarly technical authorship appropriate to our trade is there displayed.

There are reviews of progress in engineering achievement, of discoveries of principles, inventions of processes, and development of methods, in the most constructive of the sciences and the most active of the agencies promoting civilization. There are sage observations on the tendencies and needs of the times; inspiring calls to lofty ideals, and graceful tributes to the work and influence of the masters of the profession. There are the facts of the history of the profession inspiringly presented, and there are also appeals for attention to art as well as to utility.

The vast research evidently necessary to compile such records as some of the addresses are gives to the thoughtful hearer or reader an impressive lesson in the gospel of work, and it indicates qualities of mind and character that account for the authors' eminence in their profession.

In the search for and perusal of the various addresses I found myself dwelling upon the papers as well, and I was continually impressed with the originality and value of the matter there printed and preserved. A general index of the contents of the "Proceedings" would be of great value, and any member who will devote the time and effort to arrange it will find himself richly rewarded in fame and knowledge.

The value of the "Proceedings" will be enhanced by more papers and by more frequent publication. The prestige of the Club will be increased and its influence extended by early publication of its papers. Technical journals have an attraction for authors ambitious to get an audience for their thoughts, not only because of their circulation but because of the prompt publication. The editor of one of the weekly engineering papers in New York said recently that a thousand manuscripts a year are offered to him, and he finds in society publications articles that he had not had room for in his. This condition indicates that the technical societies must find their greatest strength in the stimulation of discussion in the meetings.

The relation of the engineering profession to the ordinary life of the

community is becoming closer as the profession broadens and embraces more lines of constructive activity. Few outsiders realize the dependence of the public upon the skill of the engineer until they meet a failure of his service.

The title of engineer is being appropriated by workers in fields that are hardly constructive—that have no relation to designing or directing. Some public print recently contained the appellation "human engineer" as appropriated by a doctor of osteopathy, which reminds one of the definition of that system that was given by a practitioner of another pathy as "where you get your leg pulled." The disposition to appropriate the title by unworthy individuals or classes may be regarded as a compliment to the profession at large.

The real engineer must be a man of science, competent to design, and estimate the cost of, and superintend, constructive work. To do this he must have a knowledge of the action of forces and of the properties of materials. His work is of vital importance to the public, because he is necessarily trusted to make structures safe against collapse, water-supply systems safe against pollution, and navigable channels safely clear to prevent disaster.

More lives are in the hands of the engineer than are committed to the care of a physician. Yet the engineer, with all his responsibility, only rarely achieves fame or fortune. His reward is seldom either riches or honor—merely a modest living and the joy of life that attends the satisfaction and contentment with congenial work well done—unless, indeed, he meets misfortune or makes a slip and disaster results, when he suddenly achieves not fame but notoriety. If a physician makes a mistake, it is buried underground and attributed by the sorrowing survivors to an inscrutable providence. If an engineer makes a mistake, he is buried, and the fall of his bridge is heard around the world.

Our Mr. Trautwine gave happy expression to the general view of the financial status of the profession when he said: "Nature rarely combines that high regard for rectitude so essential to the engineer, with that supreme regard for No. 1 and disregard for lower numbers, without which business mastery is practically unattainable." "Men cannot well help being poor in the practice of a profession that demands constant application of thought and study to keep up with"; which is to say that the engineer as a class cannot pursue the dollar, and the "dollar," when expressing accumulation as distinguished from comfortable sustentation, is, as a rule, not in the minds of men who are engaged in directing nature's forces. It is a case of union of taste and talent.

Professor Marburg said in one of his addresses to the Club that public appreciation of a profession and of its individual members stands in a not altogether remote relation to their earning capacity, and therefore as the overwhelming majority of engineers are employed for fixed hours at a fixed salary, their rating is relatively low.

We do not, however, appear to be unhappy because of all this. We are content to let the devotee of the dollar pursue it. He cannot get more out of life than we do with our contentment and mental equanimity. The intellectual mind has undoubtedly the greatest capacity for real enjoyment, and the educated and cultivated mind gets the most out of life.

To return, however, to the consideration of the Club's affairs. Now that we are keyed up by the interest and enthusiasm generated by the change in our standing and prospects, and the increase in our numbers, let us address ourselves to the cultivation of a loyal and fraternal Club spirit, make use of our opportunities, and enjoy all our advantages. We might with profit study the methods of kindred societies and learn lessons from both their failures and successes. A more intimate acquaintance of the members with each other is highly desirable. Many of the new members are known to only a few of us. If some practical system can be devised to enable us to identify every one we meet here, we should lose no time in adopting it. An album of photographs of the members would go far to aid in this direction and add much to the satisfaction of each frequenter of the house. Each photograph should bear the member's name, and the album be kept on the most conveniently accessible table.

We can accommodate a still larger membership, and there are doubtless many eligible engineers who would make desirable and valuable associates, who would join us if they were invited by friends. All the prominent engineers of our neighborhood should be members, and the Club should be, as Mr. Hering expressed it, a clearing house for their papers and opinions. There are many young engineers who would be helped by the companionship and inspiration that they will find here. The growth of the Club, however, will continue only as the result of special efforts by the members, for outsiders are very apt to feel that a club, so called, is a social and measurably exclusive organization, and hesitate to ask to be taken into fellowship.

The attractiveness of the house might be increased by a permanent exhibition of new appliances, and interesting specimens, or pictures of

interesting works, and the House Committee would doubtless welcome the presentation or loan of such.

The Club may, with propriety and advantage to itself and the community in which it exists, give active attention by discussion and expression of opinion to the municipal problems of an engineering nature that so frequently arise in our city and are so freely discussed by the public. The relation of our Club to the municipal life of this city might be more intimate than it has been of late. It might help by free discussion to solve the many perplexing questions that arise in regard to transportation and sanitation, disposal and distribution, communication and regulation. The case of the assistance given to the city authorities by a committee of the Club in connection with the building concrete regulations is an illustration. There should be no fear of entanglement in partisan or factional politics. A person who lives in a community and is not asleep cannot successfully pretend that he does not see and is not interested in the happenings of his neighborhood, so in time of active public discussion of a pressing municipal engineering question the avoidance of even mention of it by a local technical organization such as ours may not unreasonably be held to indicate supineness or timidity. Discussion of municipal improvements in Philadelphia may fairly be regarded as an appropriate special mission of our Club.

In concluding I desire to express my grateful appreciation of the honor done me by the Club in elevating me to the position that I now relinquish, of the consideration shown me by all during the past year, and especially of the loyal and self-sacrificing labors of my associates in the Board of Directors. The harmony of feeling and unity of action that have prevailed in Club and Board notwithstanding differences of views have been most gratifying and constitute an earnest of good things to come—an assurance that in the larger field with greater interests and more complex problems the work will be well and wisely done.

INAUGURAL ADDRESS.

PRESIDENT H. W. SPANGLER.

Annual Meeting, January 18, 1908.

I do not intend to detain you but a minute. I want first to express my appreciation of the honor you have done me by re-electing me to the presidency of the Club. It goes without saying that any man who occupies this position more than once in his lifetime is greatly honored by his colleagues.

As the new President of the Club, I take this opportunity of thanking the retiring officers of the Club for the noble work they have done during the past year. We all know that for the past ten years we have been trying to do something in the way of improving our surroundings and generally bettering our condition, and we know that, when the matter was finally taken in hand, in six months it was done, and to the Board that has just retired belongs the honor of having done it. The work has been taken in hand as engineers should take it in hand, and accomplished promptly.

The members of the new Board appreciate that the conditions under which they are taking office are quite different from those under the administration of the preceding Board, and I appeal to you for your assistance in making the coming year as satisfactory as you may desire it to be. The committee of the new Board will, I am sure, welcome any suggestions that any member of the Club may have, as, for instance, suggestions as to the better management of the affairs of the Club, or the handling of the Club-house, and we hope you will realize that it is the desire of the members of the Board to handle the Club in exactly the way you want it handled. During the coming year, the work of the Secretary's and of the Treasurer's office will greatly increase, especially the latter, because of the double payment of dues. The proposed scheme for establishing a restaurant on a small scale will also greatly increase this work. If we finally decide to establish a restaurant, we appreciate that the undertaking is one that must be handled with considerable care, and I think that in no one place can the assistance of the Club be more valuable to the members of the Board having this matter in charge than it will be in the conduct of the restaurant.

The Committee on Meetings will especially need your co-operation, as we hope that these will grow in interest and become more helpful in the new house. It is time the Club took a more active part in these

engineering projects that interest us all as good citizens as well as engineers, and I believe that more of the Club's meetings could well be spent in keeping the Club members thoroughly posted as to the many engineering undertakings that the municipality and the public service corporations are continually engaging in.

In the work of the House Committee many new problems will have to be met and mastered, and while many men are of many minds, it is hoped that with your assistance these problems may be satisfactorily worked out and the house made all that you wish for.

The financial problem will be one that will require much thought. The prospective income more than warrants the venture that we have embarked in, but a careful watch on the expenditures, and the most careful guarding against extravagance will be necessary to live within our income, and at the same time live well.

It is desired that the balance of the Club bonds be taken as soon as may be possible, there being now less than $5000 not subscribed for. It has been suggested that those who have already subscribed be asked to increase their subscriptions. This does not seem to me to be right, and we hope enough new members will come forward to close the matter soon.

It has seemed that more publicity might be given to the affairs of the Club, and there has lately been appointed a committee on publicity, to blow our own horn. You know that it is one of the failings of the good people of Philadelphia to refrain from talking about the good things we have, but to come out strong in decrying the things that are not to our liking. In the past there has seldom been a meeting of the Club of which more than a perfunctory notice has been given in the papers. There has, on the other hand, seldom been a meeting of the Club at which there have not been matters of more than passing interest presented. It is hoped that the Publicity Committee will find its way clear in the future to prepare such matters in advance, so that both the local and technical papers may be glad to get it in the most available shape. The current numbers of the technical papers with the articles relating to the new Club-house is a sample of what might often be done.

The membership Committee will be glad to act on all the applications for membership, and we hope that all the eligible men in Philadelphia may be brought to see their error in not joining with us.

Asking on behalf of the new Board your cordial assistance in making things go, I can assure you that we take office with a full realization of our responsibilities, knowing that it is only with your help that the new plans may be a success.

ANNIVERSARY AND HOUSEWARMING.

January 11, 1908.

The acquisition and occupancy by the Club of its new home at 1317 Spruce Street was an epoch-marking event in the Club's history, and it was celebrated on the evening of January 11, 1908, by a "housewarming."

As the Club had been in existence just thirty years, the occasion became also the celebration of the anniversary, and it developed into a notable function, memorable because of the large attendance of members and distinguished guests and the enthusiasm and delight manifested by all present.

The large number to be accommodated made it impracticable to assemble in form for either a meeting or a banquet, and the function was therefore in the character of a reception.

The house was tastefully decorated with palms and other potted plants and flowers, an orchestra stationed in the stair hall discoursed music, the officers and directors of the Club together with the prospective incoming officers received the members and guests in the rear parlor, and a sumptuous collation was served in the lecture room, which was cleared for the purpose.

The list of guests embraced men distinguished in engineering, scientific, educational, literary, and other professional circles and in civil government.

The Club was warmly congratulated upon the evidences of its growth and enterprise, and on its prospects for a prosperous and useful future.

The completeness of the arrangements, the thoroughness and precision with which they were carried out, secured the comfort and enjoyment of all in the large throng. The committee to whose untiring energy the brilliant success of the event must be credited was composed of Vice-President W. P. Dallett, Chairman, Treasurer George T. Gwilliam, Treasurer, and Teller H. G. Perring, Secretary, assisted by Past President James Mapes Dodge, chairman of Sub-committee on Guests, Past President Thomas C. McBride, chairman of Sub-committee on Invitations, Charles Hewitt, chairman of Sub-committee on Music, Theodore Kolischer, chairman of Sub-committee on Collation, and Herbert E. Havens, chairman of Sub-committee on Decorations.

The expense attending the occasion was defrayed by subscriptions of members.

THE JUNIOR SECTION OF THE ENGINEERS' CLUB OF PHILADELPHIA.

In February, 1908, the Board of Directors of the Engineers' Club of Philadelphia appointed a committee, consisting of Henry H. Quimby, Francis Head, Richard G. Develin, J. O. Clarke, Emile G. Perrot, and Wm. Easby, Jr., "to consider the advisability of organizing a Junior Section of the Club, for the purpose of encouraging scientific work and promoting social fellowship among the junior members."

This committee called a meeting of junior members for February 29, 1908. Twenty-one responded to this call, and these members, acting under the advice of the committee of the Board of Directors, took the first steps toward the organization of the Junior Section. Professor Wm. Easby, Jr., presided at this meeting and appointed Mr. H. E. Snyder temporary chairman of the Section. A committee was appointed to draft a letter to all junior members setting forth what had been done so far in the matter of the organization of the Section and calling another meeting for March 7th. At this meeting permanent officers were elected as follows:

President: E. J. Dauner,
Vice-President: J. F. Haldeman,
Secretary-Treasurer: Chas. S. Redding.

It was decided that a meeting should be held each month on the second Monday evening following the first Saturday.

At a meeting held March 16th it was decided to place the management of the Section in the hands of an Executive Committee, consisting of the President, the Secretary, and the chairmen of the four standing committees. The President appointed the following committees:

Publication: Edw. E. Krauss, chairman,
W. H. Pavitt,
W. Y. Heaton.

Information: L. S. Bruner, chairman,
J. I. Rodgers,
P. R. Loos.

Entertainment: Karl Nibecker, chairman,
C. H. Cox,
C. A. Bockius.

Excursions: H. E. Snyder, chairman,
W. H. Butler, Jr.,
F. H. Gilpin.

Two regular meetings have been held, at each of which a paper prepared by a junior member was presented and discussed.

The Committee on Excursions arranged for a trip through the Market Street Subway from City Hall to the Delaware River.

The Junior Section has made an auspicious beginning and the meetings should increase in interest and value, and be the means of securing for the Club a large accession of junior members, and when these members have advanced to the active grade, their experience in the Junior Section will tend to make them more useful to the Club at large.

PAPER NO. 1050.

ENGINEERING PROBLEMS IN ROAD CONSTRUCTION.

JOSEPH W. HUNTER.
(Active Member.)

Read February 1, 1908.

THIS paper should probably have been entitled "Some of the Problems Met in Organizing the State Highway Department" as more fully covering its subject-matter. The engineering problems are in themselves too momentous to be fully discussed at a single meeting of the Club, and before entering into the discussion of the subject proper some facts regarding the organization of the State Highway Department are presented. In doing this it is not intended to give a history of road-building, ancient or modern; nor to describe the Appian Way or other old Roman roads still extant in Great Britain and on the continent of Europe, but, in a short way, to call attention to what has been done in other States, and to the work being done in Pennsylvania. The work of reconstructing township and county roads by State aid was first taken up by New Jersey in 1892, followed by Massachusetts, New York, Connecticut, and Rhode Island, and Pennsylvania—sixth in line—with a State Highway Department under Act of April 13, 1903, since which time highway departments have been established in twenty-one additional States, covering the United States from Maine to California and from Michigan to Georgia. Prior to the passage of the State Highway Act several townships in the eastern part of the commonwealth had reconstructed and macadamized a majority of the roads in the townships, and Allegheny County, in the western end of the State, had, under the Act of 1895 (known as the Flinn law), reconstructed upward of 140 miles of roads, and today have nearly 200 miles improved. There are about one thousand miles of roads in the State that have been improved by townships and counties without State aid. The Act of April 13, 1903, authorizing the creating of a State Highway Department, provided for the appointment of a State Highway Commissioner, who should be a competent civil engineer and experienced in the construction and maintenance of improved roads; one assistant, who should be a capable and competent civil engineer and experienced in road-

building; a chief clerk, and an additional clerk who should be a competent stenographer. With this force the Department was organized and proceeded to carry out the provision of the Act, and to start the reconstruction of the 98,000 miles of township roads in the State—a task that seemed almost insurmountable. One of the first problems that confronted us was how best to obtain the mileage of township roads in the various counties in the State, as it was upon the basis of the

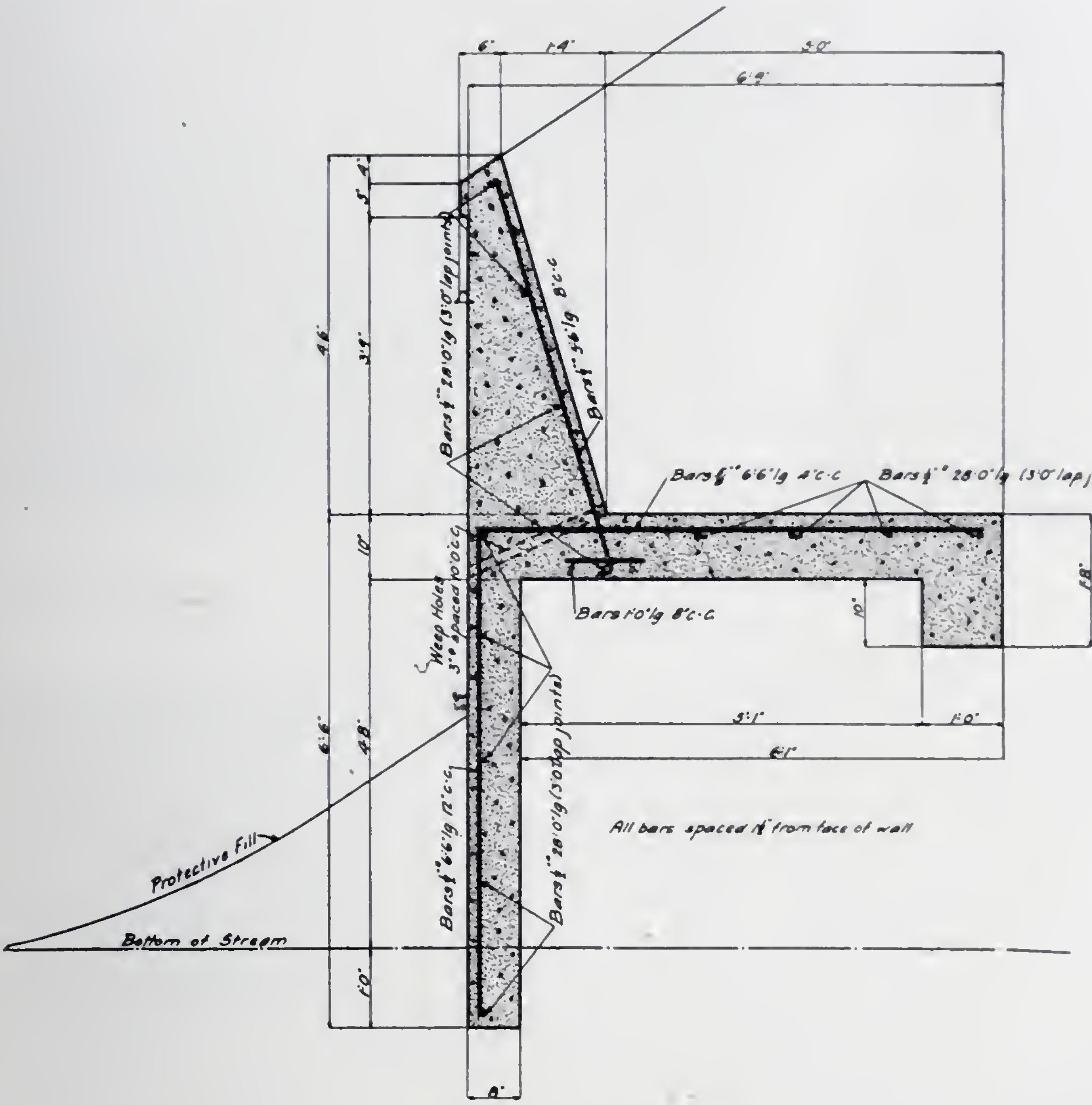


FIG. 1.—DETAIL OF HANGING PROTECTIVE WALL, ERECTED IN CRAWFORD COUNTY, SUMMERHILL TOWNSHIP.

mileage of the counties that the six and one-half million dollars was to be apportioned to the respective counties. The several boards of county commissioners were written to, asking them to furnish the desired information, but it was not until after a personal visit to many counties that the information was obtained and the apportionment made in January, 1904. Under the Act the surveys and profiles were furnished by the county authorities, who employed local surveyors to

Fig. 2.—Road in Cumberland County, Lower Allen Township; Before Improvement.

Fig. 3.—Road in Cumberland County, Lower Allen Township; after Improvement.

do the work, and some of the original plans furnished the Department are sights to behold, and in every case the work had to be done over, and in most cases I had to do it myself. This was changed by the amended Act of May 1, 1905, which, in addition to the assistants provided in the Act of April 13, 1903, provided for six civil engineers, two draughtsmen, and a book-keeper. To overcome the opposition of a great majority of the boards of county commissioners and township supervisors, and in many cases of the farmers themselves, to the State Highway Improvement Act, was a difficult problem that required serious thought and careful handling. Under the Act the supervisors of the township must take the primary step to secure State aid in the reconstruction of the township roads, and unless these applications were received there would be nothing for the Department to do, and consequently the law would be a failure. The opposition was overcome in a great measure by going up and down and across the State, attending meetings day and night called and organized by a few earnest, thorough-going men who had the courage of their convictions and co-operated with the Department in its efforts to make the law a success, so that today a majority of the county commissioners and very many boards of supervisors are thoroughly in accord with the State Highway Department, so much so that in many instances during the past summer the supervisors have requested the Department to furnish them with plans for stone arch culverts, reinforced concrete culverts, and for establishing grades on township roads in order that they might cut the hills and lessen the grades of the roads; they are also using cast-iron or corrugated metal pipe, or concrete box culverts for drainage in place of wooden box culverts, or "thank-you-marms." Another thing that has been effective in overcoming opposition is the fact that where sections of road have been built by the State Highway Department the people have found that they are not being handed a "gold brick," but are getting full value for the money expended. This is shown by the fact that there are now on file in the Department seventeen hundred and twenty-one applications that call for the reconstruction of 3395 miles of township roads. These applications come from sixty-five counties, Juniata being the only county to which the Highway Act is applicable that has not an application on file. Philadelphia County, whose city lines are co-extensive with the county lines, receives no part of the money appropriated for road improvement in the State. While it is true that there are applications from sixty-five counties, the opposition has been such in Fulton, Susquehanna, Wyoming, and Pike

Counties as to prevent any reconstruction work being done by the Department. Work was carried on successfully in fifty-five counties of the State during the past season. In five counties there was no work because the apportionment to each of these counties had been expended. The amount of the appropriation available each year is apportioned to the several counties according to the number of miles of township roads in the county. The total number of miles of township roads in the State, as returned by the several counties, is 97,940. An appropriation of one million dollars per annum gives but about eleven dollars per mile for each county for reconstruction purposes. The working season for road construction throughout the State does not average more than seven months, and the average contractor cannot complete more than one-half mile per month. If it were possible to close the roads to travel during the course of construction, a better average and better work would be obtained.

The Act of June 8, 1907, provided for an increase in the working force of the Department, so that at present I have a deputy, an assistant, twelve civil engineers, a chief draughtsman, three assistant draughtsmen, a chief clerk, four clerks and stenographers, two book-keepers, and two clerks.

The Act of May 1, 1905, placed additional work and responsibility on the Highway Department by authorizing the organization of an Automobile Bureau and the issuing of licenses. During 1907, 19,780 licenses were issued and the revenue amounting to $59,603.91, applied to the uses of the Highway Department.

The Act of April 12, 1905, known as the supervisor law, also placed additional work on the Highway Department by giving that office an oversight of the ordinary earth roads of the townships. To get in touch with the supervisors, county organizations of the several boards of township supervisors have been perfected in more than one-half the counties in the State; these meetings have been well attended and the supervisors take a great interest in them and show a desire to secure information that will help them in their management of township affairs.

The work of reconstructing township roads must be confined to the legal width of the road as ordered to be opened by the court. Usually this width is 33 feet, sometimes 40 feet, and in a few instances 50 feet. In many instances it is a difficult matter to establish such a grade as is desirable and to provide for suitable drainage, which is the fundamental principle of all road-building. By erosion and abrasion the road-bed that had originally been on a level with the land on either side

Fig. 4.—Old Bridge in Crawford County, Summerhill Township.

Fig. 5.—New Bridge in Crawford County, Summerhill Township; False Work Still in Position.

of the road when opened has become depressed in many instances from two to five feet or more, forming a channel for the rain-water which, as a usual thing, is permitted to flow in the center of the road, and which, in many cases, has to be carried from 500 to 3000 feet before an outlet can be obtained. While the Act of 1836 provides that—

> "The Supervisors aforesaid shall also have power and authority as aforesaid, to enter upon any such lands or enclosures and cut, open, maintain and repair all such drains or ditches to the same, as they shall judge necessary to carry the water from the said roads,"

it is a difficult matter to secure new outlets for the water in thickly settled communities, but so far the Department has been able to secure what has been needed. In draining some roads it has been found necessary to dig a trench 500 feet or more in length in the center of the road, place a five- or six-inch tile in the bottom, and fill up the trench with broken stone. Sometimes these drains are placed at the side of the road underneath the surface gutter. Many hills that show a wet subgrade are drained by a herringbone system of tile drains extending alternately from the center to either side and placed 25 to 50 feet apart. In determining the size of pipe to be used at a specified location, the area to be drained is considered, and the rule that a 12-inch pipe is sufficient to carry the average rainfall on fifty acres is applied and the size of the pipe or culvert increased from 50 to 100 per cent. to cover extraordinary downpours. Again, where there are pipes or culverts in place that have gone to decay and need replacing, a careful observation is made of high-water marks, and a pipe or culvert is placed of the required size. Very seldom is an old pipe or culvert found large enough. Last July we reconstructed a section of road in Bendersville, Adams County. The engineer who made the preliminary view for pipage concluded that at a certain place it would be necessary to replace a pipe, placed to take care of the water that came down the valley, with a 14-foot span reinforced concrete. The supervisors and people of the township living in the neighborhood thought it was a useless expenditure of money, and persuaded the engineer to leave out the concrete culvert and put in a 24-inch pipe where formerly there had been a 12-inch pipe and there the water had slightly overflowed the road. Just after the 24-inch pipe had been installed, on a Saturday afternoon, there came a heavy downpour of rain, the water

filled the 24-inch pipe and went over it, destroying about eighty feet of the road. The writer went to Bendersville on the following Wednesday, made a personal examination, and concluded that it was necessary to put in a culvert, but the supervisors and residents would not believe it, and said that while there had been such a rain, it was not apt to occur again in a good many years, and the 24-inch pipe would carry all the water. However, within a couple of hours a second downpour came, which, if anything, exceeded the rainflow of the previous Saturday. The bridge is now in place. Most of the drains to be found along the old roads are built of stone with either the side walls or covering fallen down, or a 12-inch by 12-inch wooden box choked with mud or leaves. The Department uses cast-iron and corrugated metal pipe as conduits for water; also, concrete box culverts and culverts made with concrete sides and covered with reinforced concrete slabs.

Bridges are made of reinforced concrete, rubble cement masonry, and plate girders with concrete floor. To my mind, the stone arch or reinforced concrete structure is more in harmony with the landscape, and therefore more suitable for use in road reconstruction, than the stiff steel plate girders. At this point I will give some details of a reinforced concrete arch bridge recently erected over Montgomery Run at Conneautville, Crawford County. The old bridge was a through timbered truss, with iron tension members resting on dry masonry abutments.

The span of the arch is 50 feet and the rise 6 feet 9 inches from the springing line of arch, making a very flat structure with a great horizontal component at the skewbacks. The road traffic carried by the bridge is heavy, and the stream crossed at this point is unique for its turbulent floods, followed by intervals of low water. The foundations were to be carried to a depth of four feet below bottom of the stream. The top stratum was found to be gravel, interspersed with boulders; this in combination with the water made excavation difficult. The pits for the abutments were, however, dug and borings made to determine the nature of the underlying strata. The drill brought up quicksand in both pits, to a depth of from eight to twelve feet on the west side, and to a greater depth on the east side. Piles were driven on both sides in sufficient number to carry the entire vertical reactions of the bridge. Concrete, the consistency being a hand-mixed, semi-dry, or dry, 1–3–5 mixture, was deposited by means of a slide, until above water, after which it was shoveled directly into the pit and pushed gently off the top of the heap into the water. The latter was retained by means of

Fig. 6.—Road in Perry County, Howe Township; Before Improvement.

Fig. 7.—Road in Perry County, Howe Township; During Improvement; Showing Change in Grade.

small earth dams so as to prevent loss of cement. The sand was mixed dry three times with the cement and then the broken stone wetted and turned four or more times with the mortar. The concrete was well tamped and spaded, and while the concreting progressed, work was pushed on the forms and centers. The ribs were built and assembled on a platform over a full sized drawing, the material being green maple; bolts were used for the joints. Eight-inch by ten-inch timbers make the compression chords and 2-inch by 8-inch and 3-inch by 8-inch planks the tension chords. The nature of the stream made it necessary to support the ribs at the ends only, so as to leave the waterway unobstructed. The trusses, eight in number, rest upon pairs of wedges, which in their turn rest upon a horizontal 8-inch by 8-inch stringer supported by transversely braced posts, resting on mud sills laid over transverse blocks on the bottom of the stream. The lagging is matched and planed 2-inch hemlock boards, nailed in place. When the concreting reached the springing line of the arch, the composition of the mixture was changed to 1–2–4, owing to the coldness of the weather, and this mixture was used exclusively until the bridge was completed. Whenever fresh concrete was deposited upon already hardened surfaces, the latter were cleaned thoroughly and given a coating of neat cement for a binder. Johnson corrugated bars having an ultimate tensile strength of 65,000 pounds or more per square inch were used in the reinforcing.

Deducting the cost of piling and the cost of the extra concrete used, the bridge cost $2603, or fifty-seven dollars ($57) more than the estimated cost.

Fig. 1 shows the proposed continuation of the northeast wing wall of the 50-foot clear span reinforced concrete arch bridge just described. Its peculiar construction is due to the fact that about five feet below the stream the gravel stratum rests upon quicksands. The expense of piling for foundation to allow the erection of a solid wall would be too great. A line of piles could, however, be driven and allowed to stick up high enough to form a retaining wall, but the appearance of a bank of this kind would not harmonize with the bridge, neither would it last very long, nor would it recommend itself as being economical. The proposed wall appears to overcome these various difficulties, as it does not require a solid footing, hanging as it is in the bank itself; it is economical and permanent, and presents a surface harmonizing with the general outline of the bridge. The remaining consideration is its strength; will it stand up and fulfil its functions?

We will consider the part above line A-A.

In accordance with the prevalent theory of earth pressure, there is a maximum resultant pressure of about 122 pounds per square inch, while concrete is considered good for 300 pounds per square inch. The weight of concrete is taken at 150 pounds per cubic foot, and that of the earth backing at 100 pounds per cubic foot. There would be no tension, the resultant falling within the middle third, but to be on the safe side we will consider the horizontal component by its lever arm, which gives a bending moment of 5580 inch-pounds. This, if made to equal the internal moment, will require a lever arm 3.45 inches long, if bars one-fourth of an inch square are spaced 6 inches center to center, and if the tensile value of the iron is equal to 12,000 pounds per square inch and the compressive value of concrete equals 122 pounds per square inch as above. This would require a slab only 6½ inches thick at the base, while we have 1 foot 9 inches. If the bars are stressed to the maximum, they will not pull loose at the bottom, as it would require more than 3000 pounds per bar to rip the transverse bars to which it is hooked, through the concrete. The bars are increased to three-eighths of an inch square as the hook on the one-quarter inch bar would not be strong enough. The horizontal shear along line A-A is amply taken care of. It would require at least 10 pounds per square inch to drag the ledge B horizontally through the ground; the horizontal components above and below A-A can never accomplish this. In case of water freezing above A-A, the inclined back of the wall would allow the ice to slide up rather than push right out. Weep holes are provided, as per sketch, to prevent freezing as far as possible.

The horizontal slab below A-A sustains nothing but horizontal tension equal to the sum of the horizontal components above and below A-A: that is, providing it and the ledge B are resting on unyielding soil. In case of settling of one form or another the slab will sag and perhaps crack at the center or the ends, but the reinforcing bars, which are arbitrarily chosen, will amply take all horizontal tension, and they, in combination with the earth fill, will prevent any overturning above A-A.

The perpendicular slab below A-A carries about 1200 pounds direct compression, being the vertical component resulting from the loading above A-A: the horizontal component is taken care of by ledge B. The vertical component plus the dead weight of the slab equals 1800 pounds or 2700 pounds per square foot, which is not very high for a gravel bed about four feet deep. In case of a tendency to sink, the hor-

FIG. 8.—ROAD IN CUMBERLAND COUNTY, EAST PENNSBORO TOWNSHIP; BEFORE IMPROVEMENT.

FIG. 9.—ROAD IN CUMBERLAND COUNTY, EAST PENNSBORO TOWNSHIP; AFTER IMPROVEMENT.

izontal slab will prevent it from going far. There is a slight horizontal component at top and bottom, caused by the backing, but this is amply provided for, as is the bending moment at center. The rods are spaced in accordance with the Department's standard for slabs under such loading. A range in temperature of about 100 degrees is taken care of by longitudinal rods aggregating in total cross-section a $\frac{1}{600}$ part of the cross-section of the wall; twelve bars three-eighths of an inch square are distributed through the section for this purpose. This, I

FIG. 10.—ROAD IN CENTER COUNTY, RUSH TOWNSHIP; BEFORE IMPROVEMENT; SHOWING OVERFLOWED ROAD.

believe, demonstrates that the wall will safely carry all the earth pressure imposed upon it during changes of temperature; it will also resist the pressure caused by freezing above line A-A; and to overcome any injury by freezing below A-A, it is purposed to fill inside the wall with clean gravel or cinder a foot thick.

The problem of suitable material for road construction is one that has required much thought, and is today one of serious consideration and might alone be given a night of study and discussion. There are mountains of stone in the State, but the natural deposits of stone that make a

good road surface are scarce. The best material is trap rock, and the quarries in which this stone is found are confined to the eastern part of the State. Out of the twenty-eight varieties of limestone to be found in the State, only eight or nine have been found to be suitable for road purposes. Chemung rock, which is found in quantities in thirty-four counties, is of little use in itself except for telford foundation. The Shenango sandstone in the western part of the State, and the Pocono sandstone in the eastern part, are in the same class with the Chemung rock, the difficulty being that while in many instances they are hard enough, they have not sufficient adhesiveness to keep the bond under ordinary traffic, but would give good service under the traffic in and adjacent to centers of large population. The shales found throughout the State are of little use for road purposes, except for very light travel, the Marcellus shale found in Pike County being the best. Colonel H. C. Demming, State Geologist and Chemist, has been making some tests and experiments for the Department combining various rocks with limestone, and the results show some wonderful and interesting facts, one of the best being the combination of 50 per cent. of Berks County granite, having but 6 per cent. binding quality, with 50 per cent. of Porter Township, Huntingdon County, limestone (Lower Helderberg), having 22 per cent. binding quality, and 15 per cent. of water added, the test showing the combination to have a binding quality of 97 per cent. A few practical tests show results that are very encouraging and which warrant the making of further tests and experiments.

In some sections of the western part of the State county commissioners, supervisors, and citizens are very insistent on having brick pavements, and some have been laid as an experiment. The telford-macadam system of construction is generally used because the native stone, which is usually a sandstone, can be used for the telford-foundation, but when crushed for macadam construction is practically worthless, there being from one-fourth to one-third loss in crushing, and the stone grinding to dust very quickly under traffic. The great objection to limestone is that it absorbs moisture quickly in wet weather and the passing traffic soon makes a muddy surface; in dry weather there is a dusty surface to contend against, and roads upon which limestone has been used have been condemned as not having been properly constructed, and the Department freely criticized for using such material, but to have used trap rock would have been prohibitory. This brings up the problem how best to get rid of the dust nuisance and at the same time provide a covering that will preserve the bond in the surfac-

ing stone and serve the purpose of preventing the water from penetrating the road surface. Experiments have been made with "Tarvia" and "Asphaltoilene" which show that a smooth surface, practically free from dust, can be obtained which will for a time withstand the weather, but the material will have to be applied every season, and the cost —about $600 per mile—makes it expensive and therefore its use prohibitive in most townships. The application of these materials must be made in hot weather in order to secure any effective results. I believe that an application of coal-tar will be as effective as any material that can be used, and I am fully convinced that with the assistance of the State Chemist, Col. H. C. Demming (who is making some tests in this line for the Department), we will obtain a lasting binder and dust settler at a cost much less than that of the other preparations.

In establishing a grade line on a section of road to be reconstructed it is the practice of the Department to do as little grading as possible and, as a rule, to make the cuts equal the fills. It is a difficult matter to lay a grade line through thickly settled villages that will suit every property owner, and consequently we have kicks innumerable, protests, petitions, resolutions, and injunctions. Usually these objections are overcome after a short delay and the citizens come to their senses when it becomes a question of having or not having the road improved. By grading and change of alinement the percentage of grade in most instances has been materially lessened. It would be desirable, if possible, to have no grades of more than 3 or 3½ per cent., but with varying surfaces in the State this is found to be impracticable, and for short distances in some localities we have been fortunate in reducing a 15 or 20 per cent. grade to a 10 per cent. grade. On the old Hazleton and Nescopeck turnpike at Conyngham in Luzerne County, by change of alinement which increased the length of the road 925 feet, the old grade, which ran from 5 to 16 per cent., was reduced to 8⅔ per cent. as the maximum, and 2.46 per cent. for the minimum. It is at times more desirable to cut down a hill than to seek a change in alinement in order to secure an easier grade. Property owners who have established their residences along the road oppose a change of location, and then, again, the property owners whose land would be taken by the change ask such excessive damages that it is less expensive to cut the hill. You can readily understand that where a section of road passes over a hill which could be removed to advantage, it is practically useless to do so when just beyond is a hill the grade of which is greater than the one that

could readily be changed, and which cannot be materially lessened either by a change of alinement or by cutting.

Another problem of difficulty to which has been given much thought and serious attention is that of "extras" for which the contractor asks to be paid, and for which in most cases he is justly entitled to compensation. Road survey and map is required to show the center line of the road as traveled, the side or fence lines, ditches, buildings close to the line of the road, and every stream and location of old pipes and drains; also a profile of the center line, cross-sections every one hundred feet and at every change of grade which shall extend fifty feet on each side of the center line, and elevation of porch or door-sill of abutting residence. After the map has been prepared the road is visited either by myself or assistant, the grade line that has been suggested on the map verified or adjusted on the ground, and the sizes of drain-pipes, bridges, and culverts determined. After these data have been obtained and placed on the map an estimate is made of the cost and certified to the county commissioners and board of township supervisors or commissioners with a letter which they are requested to sign and return to the Department, in which they state that they are satisfied with the estimate of cost and request the Department to proceed with the work. Bids are invited and are usually within a few hundred dollars of the estimate. A contract is made for the lump bid, but all unit prices are fixed at the time the bid is made, on blanks furnished by the Department. After the bids have been received and it has been determined which is the best, agreements are sent to the county commissioners and the board of township supervisors to sign. The amount of the contract is set forth, of which amount they not only agree to pay their respective shares, as also of the total cost of the work. When the work has been completed and the cost therefore certified to them, they as a rule demur as to payment of "extras," which at times seem to be pretty heavy. With all the care taken it seems almost impossible to avoid having some extras, and yet there are occasions when there are none, and even times when upon final estimate the contractor is paid less than his lump bid, there being a clause in the specifications that provides for such adjustment of contract, but it is a difficult matter to convince the commissioners and supervisors that the extras are just and the contractor should be paid, and in fact there are a few cases where it has been impossible to convince them, and their account with the State is unadjusted. The State pays the contractor

and afterward collects from the county and township their respective shares, being together 25 per cent. of the cost.

The general specifications call for a bottom course of 5 inches of 3-inch size stone for macadam construction, or 5 inches of stone for a telford construction, placed upon the earth foundation after it has been thoroughly rolled and compacted. After the foundation course is laid there is placed upon it 6 inches of 1½-inch size stone which is covered with rock screenings and the whole rolled to 4 inches as a second or top course, making in all 9 inches of stone roof to protect the earth foundation, the gradient being a slope of ½ inch per foot from the center to the side of the stone road bed, which is usually 16 feet wide, 12 feet being the minimum width allowed by law.

The Act of April 13, 1903, appropriated the sum of $6,500,000 for the reconstruction of township roads to cover a period of six years, of which sum 10 per cent., or $650,000, was set aside for maintaining the highways reconstructed by State aid, or that had been or might hereafter be reconstructed by the several counties or townships themselves. In addition to the original sum, the Legislature of 1907 appropriated $3,000,000, but this sum was reduced by the Governor to $1,000,000, making a total of $6,850,000 to be used in reconstruction work during the six years.

There have been fully completed and accepted by the Department 324.5 miles of road at a total cost—inclusive of bridges and culverts—of $3.325,520.29, being $10,248 per mile, or $1.94 per lineal foot, an increase over the average price—$1.68 per foot—prior to January 1, 1907, occasioned by increased cost of labor and material. The cost of bridges and concrete culverts, included in the above total cost, is about $155,000. There under are contract 224.1 miles, the contract price of which is $2,321,197.37, of which about 100 miles are practically completed. The average of all extras on completed work is 11.1 per cent. The average cost of inspection is 3 per cent. of the cost of the road, and the average of engineering expenses is 2 per cent.

The Act of April 10, 1905, placed the care of the old National or Cumberland Road in the hands of the State Highway Department. Improvements are being made to the road, but as the hour is getting late that subject will not be discussed tonight. With your permission I shall be glad at some future meeting to submit a paper concerning the "Old Pike" and other historic highways of Pennsylvania.

DISCUSSION.

Col. Henry C. Demming (Visitor).—As an illustration of what the State highway engineers are doing; five years ago, if we went from our club-house in Harrisburg to Fairview, a distance of five miles, it would take two hours, and since the road has been improved an automobile can do it in twelve minutes. We put some material on that road that is supposed to prevent dust, but it has not done it, but we will probably have a material on that road this year that will do it at a cost of less than one cent per square yard. Once we tried some water-gas tar and crude petroleum, and the whole coating burned up, so we had to put another constituent to that, and we are now going to add still another constituent, so that the physicians of the locality will say to their patients: "If you want to get well, just drive over that road." Some material was sent in from Tioga County which was found upon analysis to be the best material for Portland cement, and it had never been noted by any geological survey, although it is within a quarter of a mile of a railroad track on a branch of a trunk main line. In Huntingdon County we found some rock, by experimental tests, to be the equal of any Portland cement rock in the Lehigh region. Some time ago we examined a rock known as ganister, found in Blair County. The analysis showed 99.54 per cent. silica, and at that time was being unloaded from France 3000 tons of silicate at $4.00, and this ganister rock selling at 40 cents a ton.

So the Highway Department is not only improving the roads of the State, but developing materials that will be of very great commercial importance to our commonwealth.

E. F. Miller.—Much of the dissatisfaction with the road law, or its administration, in rural communities is accounted for by the fact that the State is building suburban streets, not rural highways. This is entirely different from the general expectation of the working of the road law, at the time it was passed, and there is keen disappointment and much harsh criticism, as a result. To build a $35,000 road to benefit a few square miles of $0.50 or $1.50 land does not appear to be an economical proposition. The State, at less expense, could buy this land for the forest reserve.

The general level of the condition of country roads is not being raised by building a few isolated macadam roads between centers of population, usually well served by steam or electric roads, nor by building mountain roads to summer resorts. The dirt road, which predominates, and will predominate for several generations, at the present rate of State improvements, is receiving no recognition nor aid. Did the law permit, a grant of $500 per mile to a township would, in general, make the worst places passable at all times of the year, and so improve the grading and drainage of the moderately good road that it would be better than putting roller bearings on every wheel in the township. Further, there is no need for building wide roads through lands where possibly forty or fifty teams a day is the maximum travel. Where it is absolutely necessary to macadamize, a narrow road, costing less per mile, is of much more value to the community than half the length of a wide road.

Further, except in certain places, there is no necessity for bridges wide enough for teams to pass each other. On old highways in the State there are many single-

track bridges, which have carried the traffic satisfactorily for a hundred years or more. The cost of three wide stone bridges will usually build four or perhaps five narrow ones; and if useless finish is omitted, seven or eight. The question is one of economical expenditure, of obtaining the greatest benefit for the greatest number of people.

That provision of the law requiring specifications, advertisement for bids, and signed contracts is also a cause of added expense and of indifference, and in some cases hostility, to road improvement among farmers. While it is true that the township has the privilege of bidding, yet the supervisors are usually not men skilled in reading specifications, and they do not dare to take the risk of underestimating if bound to a contract. In consequence, the distribution of State or township funds is usually to the employees of a contractor who brings men from outside the township.

These supervisors are, however, usually men of some executive ability who can handle men and materials economically, and if they were permitted to spend moderate amounts of State appropriations under certain general restrictions, somewhat in the same manner as the school appropriation is spent, the benefits would be very much extended, and dissatisfied criticism, now so prevalent, would disappear.

Instead of waiting four hundred years for the last piece of road to be improved, the entire road system might be benefited, to the extent of perhaps 10 per cent. in ten years.

Mr. Hunter (in reply to questions).—There had been considerable talk about the State reconstructing main lines of travel both east and west and north and south without depending on the townships and counties to assist in the work, and at the 1907 session of the Legislature a bill was passed providing for the reconstruction of such main highways, and the sum of one million dollars was appropriated to commence the work, but owing to the lack of sufficient revenue the act was vetoed. Nothing further can be done on that line until after another act is passed and appropriations made.

The Highway Department has used furnace slag for bottom course in place of native stone for telford with good results. The use of slag for top or finishing courses has not been productive of good results.

In constructing macadam roads in Jenkintown and in Abington and Cheltenham Townships, Montgomery County, about 1891 to 1894, slag from the furnace at Edge Hill was used for the bottom course and Howellville blue stone and Cedar Hollow limestone for the top courses. The Howellville bluestone gave the best results as a wearing material.

But little gravel is to be found in the State suitable for road-building purposes. Some bank and river or creek gravel has been used for bottom courses, but is always covered with limestone for the top courses.

Most of the gravels found in New Jersey make a good road surface on the sandy subsoil of that State, and have in themselves sufficient binding material, and are used extensively in road reconstruction in the State. By the use of gravel New Jersey has been able to reconstruct roads at a less average cost than roads have been reconstructed in Pennsylvania.

The cross-section of a road reconstructed by State aid shows the sub-grade to have the same slope from the center to the sides as the finished road-bed.

This is usually $\frac{1}{2}$ inch to the foot, but is increased somewhat on steep grades to as much as 1 inch to the foot. A road that has a surface nearly level or with but little grade provides a greater wearing area and will not become rutted as quickly as a road with a high crown. A horse pulling a vehicle, loaded or unloaded, will move along the line of least resistance, and this he can do when the load he is pulling is as nearly level as possible, and he accomplishes it when he walks on the center of the crown.

Macadam can be maintained on grades of 10 per cent. or 12 per cent., but at a greater cost than on grades of less percentage. If the gutters are properly constructed, rain-storms have but little effect on a macadamized road on a hill.

In Jenkintown we have successfully maintained macadam on grades of 12 per cent. for twenty years. Most of our streets are macadamized—we have but little brick pavement. Macadam construction on hills I believe to be better than telford-macadam construction.

After the roads have been reconstructed by the State, the supervisors are supposed to look after them and keep them in repair, the State paying, under the Act of 1905, one-half the cost of maintenance.

The supervisors in most cases have not paid any attention to the reconstructed roads—have not even kept the ditches open; but under the act of 1907 the Highway Department is authorized to take charge of the maintenance, see that the roads are properly maintained, and collect from the townships and counties their respective shares of the cost of such maintenance; the State paying three-fourths and the township one-fourth of the cost.

To maintain a macadam road properly, material—crushed stone—should be kept along the road so that it can be applied just as it is needed. A road upon which the surface has been allowed to wear out entirely, should be rounded up, filling up the ruts and raising the center with native stone, either crushed or broken by hand, rolled down and then covered with four to six inches of loose crushed limestone or trap rock, which should be thoroughly rolled and compacted.

There is but little difference in the quality of trap rocks used for road construction in the eastern part of Pennsylvania, and the same material is used for the binder as for the $1\frac{1}{2}$-inch stone, because the trap rocks used have a high percentage of bind-quality and also a high percentage of wear.

In France I believe the material is placed in piles along the road, and every mile is in charge of a man who must be on the road every day, including rainy days, as at such a time he can readily see where the low spots are and where drainage is needed. Until we adopt some such system our money for stone roads will not be spent to the best advantage; to get the full benefit of a stone or macadamized road, it should be maintained in perfect condition at all times.

At a cost of $10,000 per mile, even if land is not worth more than $20 to $30 per acre, I believe that most of the townships in the State can afford to improve their main highways; it means but $1250 per mile to the township.

One of the first roads reconstructed by the State Highway Department was in Tobyhanna Township, Monroe County. It cost $35,000 for seven miles, including three bridges. The road was deep with mud in the spring and deep with sand in the summer-time. It usually took about one and a half to two hours to drive the seven miles, and now it requires about forty minutes. There were probably thirty to forty houses along the line of the road. The land was grown

up with scrub oak and huckleberry bushes, and I think was assessed for fifty cents per acre. There are now eighty to one hundred houses along the line of the road and the land is assessed at $1.50 per acre, and I understand that there has been a recent sale of some land at $10 per acre.

During the past year Tobyhanna Township has paid one-quarter of the cost of extending the road five miles to meet the Wilkes-Barre and Easton Pike. The adjoining township of Coolbough has an application asking for the reconstruction of five miles from Mt. Pocono to Tobyhanna, showing that these people whose land will not sell for more than $10 to $20 per acre realize the great benefit that will accrue to them from having good roads, and they are willing to put up their share of the cost in order to have them. I find the same thing all over the State.

A main road passing through a borough will be reconstructed with State aid in a manner similar to the roads in the township, provided, however, that the road in the township has been reconstructed to the borough line and the borough is unable to bear the total cost of reconstruction. A township or a borough can make such application for road improvement and agree to pay one-fourth of the cost, and thus relieve the county of any expense. This has been done in a number of instances where the county commissioners have refused to act.

A heavy automobile running at a high rate of speed rapidly removes the binding material from the road, and stones one inch in diameter have been observed to be sucked out of the road surface by a swiftly moving machine.

Commissioner MacDonald, of Connecticut, has been making some experiments with a mixture of coal-tar and crushed stone in repair work. It makes a good dust preventive and produces a road surface probably better than asphalt.

It is not possible to reconstruct township roads in the manner now being done by the State Highway Department for $500 per mile. That sum would not put the drainage in, and while the average cost has been about $10,000 per mile for the work done, many of the roads have been built for $5000 per mile.

Bridges must be rebuilt and enlarged, and while the present structures will accommodate a single team and an ordinary load, the county courts have decided that the township bridges must be made to accommodate the traffic and the traveling public, and if the township bridge will not permit of the passage of a fifteen-ton traction engine or steam road-roller, the township supervisors will get themselves in trouble.

It costs the farmers of Pennsylvania four and one-half million dollars per annum to make the so-called repairs to dirt roads, and it would be a useless waste of money to apply any portion of the appropriation made for reconstruction work to the repairs to the dirt roads.

The automobile law requires an application for a license to be made each year and the same form of affidavit has to be made. The Highway Department can issue licenses only when the form of application as prescribed by the Act has been complied with.

Paper No. 1051.

SOCIALISM.

As Illustrated by Papers Recently Presented to The Engineers' Club of Philadelphia.

JOHN C. TRAUTWINE, JR.

(Active Member.)

Read April 4, 1908.

Like most other words, "socialism" is variously defined. The popular mind confounds it with its opposite, anarchism, and thinks of "red-handed socialists" and "bomb-throwing socialists." The socialist agitator seeks the enactment of laws making all men equal (as the Declaration of Independence says they were born). The word "socialism" is here used in its wider sense, as meaning that tendency toward co-operation and organization which has marked every step of man, from the savagery of his primitive individualism to his present condition of modified barbarism; the tendency which has given us the post-office in place of the courier, the Pennsylvania Railroad in place of the Conestoga wagon, and municipal water-supply instead of the individual well; the tendency which has brought us together in an Engineers' Club; the tendency which, advancing a step further, has brought all but one of the national engineering societies under a common roof, and a dozen of the local societies into a joint publication concern; the tendency which enabled our forefathers to transform thirteen British colonies into as many states, and then to unite these states into one Union; the tendency which may yet save the forests, so nearly destroyed by individualism; the tendency which, as its logical outcome, must lead to the socialization of all business, and which will thus abolish poverty and (with it) most other vices and follies, including patriotism, for

> "War is a game which, were the people wise,
> Kings could not play at,"

and the unwisdom of the people is less and less in evidence as it becomes more and more subjected to intelligent and concentrated business authority, unaffected by the patriotic mania.

This tendency, here called "socialism," is inherent in the nature of things, and it can therefore afford to smile complacently, alike upon the friendly efforts of socialistic clubs and upon the opposition of newspapers and respectable people.

One of the striking peculiarities of the human animal is the readiness with which it accepts improved conditions and forgets that the previous conditions ever existed. We laugh at the man who spells "although" without the "ugh"; and we forget our debt of gratitude to the crank who braved the ridicule of our ancestors by dropping the "k," which is equally necessary and beautiful at the end of "musick." We take up our abode in a new place at the world's end, and straightway feel as though we had always lived there. We acquire a new Club-house, and, if it were not for the photographs, so happily taken, of the old quarters, we should soon be forgetting that we were not always here. Marconi gives us the wireless telegraph. At first blush we are incredulous; but our incredulity is quickly succeeded by the sense of never having been without the wireless. Indeed, our readiness to adapt ourselves to new conditions very generally takes the form of inability to recognize that any change has taken place.

If we consider recent developments in the business and engineering world, including notably several papers recently read before this Club, we must be forcibly impressed (1) with the extent to which the methods of socialism are, and have always been, in operation in civilized countries; (2) with the increasingly rapid growth of this feature, especially during recent years; and (3) with the obtuseness of the general public in failing to discern these signs of the times.

Orthodox political economy denounces as socialistic any system under which the improvident and shiftless share, equally with the provident and thrifty, in goods produced at the public expense. Such a system, we are told, puts a premium upon improvidence and shiftlessness, and thus tends inevitably to the demoralization of the people. Orthodoxy insists that, in order to make such a system possible, "we must first change human nature."

And yet, from time immemorial, we have enjoyed highways, used by the improvident and shiftless equally with the provident and thrifty, although constructed and maintained at public expense. This is pure socialism, and we all think it a capital thing.

For years we have enjoyed public parks, similarly constructed and maintained; and public schools, which struggle, only too hopelessly, to undo the mischief done in the individual home.

For centuries we have enjoyed public water-supplies almost equally socialistic, and others operated by corporations whose management is eminently socialistic, when contrasted with that of the private pump and cistern.

The state still seems to think she can afford to let millions of her citizens go underfed, but she has at least learned that she cannot afford to allow them to go unwashed; so she already provides, at her own expense, public baths, which any citizen may enjoy, free of charge.

Orthodox political economy denounces also, as inimical to the public welfare, any interference with the fullest and freest individualism; and yet, at our meeting of December 21, 1907, Mr. Sterling, Forester for the Pennsylvania Railroad, told us how the general government was striving, by socialistic effort, to avert the ruin of our forests, threatened by the crimes of individualism, and how "the Division of Forestry, of 1898, with eleven men and an appropriation of $28,000, had grown into the Forest Service of 1907, with a force of 1400 men, an appropriation of $3,100,000, and an organization which carries on work in practically every State in the Union," with "full control of about 150 million acres of national forests in the West, an area greater than all of New England, New York, Pennsylvania, and New Jersey combined, worth in the aggregate over a billion dollars, or more than the property value of either the army or the navy."

The Secretary of Agriculture has just made a report upon the advisability of the purchase of the Southern Appalachian and White Mountain watersheds for national forests.

For years the United States Geological Survey has been engaged upon the construction of a topographic atlas of the country, the separate sheets of which, if prepared by individual enterprise, would probably cost us at least a dollar each, while socialism gives them to us, splendidly lithographed, almost for nothing.

At this moment the general government, in total disregard of the supposed fact that all prosperity depends upon competition between individuals, is digging an international socialistic canal connecting the two oceans, for the benefit not only of all its own citizens but of the human race, and it is reported that, in view of this, "Senator Knox, of Pennsylvania, in an address before the Pittsburg Chamber of Commerce, on February 12th, took advanced ground in favor of radical extension by the government of its work of waterway improvement," and the editor of "Engineering News" says: "We are in full sympathy with

the idea that large and liberal expenditures for waterway improvements should be undertaken."

At the meeting of the Club, February 1st, Mr. Hunter, our State Highway Commissioner, told us how our own State government is substituting intelligent central control of public roads for the haphazard and relatively individualistic efforts of local supervisors, and how the personnel of this service, too, within a score of years, has been increased several hundred per cent.

Our State Board of Health, also, bids fair to bring about betterments never before secured, if indeed ever seriously attempted.

The President of the United States has invited the governors of the several States, and representatives of our national engineering and scientific societies, to attend a conference, at Washington, "relative to a proper conservation of the natural resources of this country."

Our neighbors in Massachusetts, with characteristic progressiveness, recognizing the folly of the unseemly scramble between municipalities for water-supplies and for sewage disposal, have set an admirable example in the formation of the Metropolitan Water and Sewerage Board, including Boston and several smaller communities; our own State of Pennsylvania has its Water-supply Commission, under the Chairmanship of our Past-President, Mr. John Birkinbine; and it will be strange and unfortunate if President Roosevelt's action does not shortly lead at least to the formation of interstate boards, to collect interstate streams, and distribute water among the cities, as the cities now distribute it among their citizens.

A hundred years ago the iron industries of our country were operated by a handful of obscure individuals, each with his little bloomery or forge or baby charcoal furnace, hidden away in some remote valley. Fifty years ago infant corporations had begun to take hold of this business. Today, by reason of mergers, we find this interest in the hands of a few giant corporations, which, by concentration of capital and by organization of industry, have brought about improvement and uniformity of output and reduction of cost, hopelessly impossible under the old conditions; and much the same thing has happened with the transportation interests; until we now find the States and the general government waging the battle to determine whether the governments are to control the corporations, or vice versa.

Thus the corporations are rendering double service. They are teaching us, at one operation, (1) the overwhelming economies obtained by co-operation, by the organization of individuals into masses, and (2)

the folly of entrusting to private interests these matters of public concern.

And yet an overwhelming majority of our people either laugh at socialism as a dream, impossible of accomplishment, or deprecate it as a monstrous evil, while a small but growing minority (like passengers who would get out and push a train going twenty miles an hour and gaining speed) assembles itself in societies formed for the purpose of forcing socialism upon the unwilling majority. A highly intelligent and educated gentleman recently expressed to me the conviction that socialism could never take root in our country.

Both majority and minority are unable to see what is going on before their noses.

Twenty years ago Bellamy predicted that the merger of corporations would proceed until it resulted in one giant corporation, whereupon the people would awaken to the situation and take over the business into their own hands; but, in view of the general failure to realize the extent of the progress already made, it seems that Shaw was nearer right when he said: "The practical abrogation of Property, as it exists at present, will occur without being much noticed."

"To the masses of men, the intelligent abolition of property would mean nothing except an increase in the quantity of food, clothing, housing, and comfort at their personal disposal, as well as a greater control over their time and circumstances."

"The total abolition of property, and the conversion of every citizen into a salaried functionary in the public service, would leave much more than 99 per cent. of the nation quite unconscious of any greater change than now takes place when the son of a shipowner goes into the navy. They would still call their watches and umbrellas and back gardens their property."

Paper No. 1052.

MALLET TYPE ARTICULATED LOCOMOTIVES.

GRAFTON GREENOUGH.
(Active Member.)

Read March 21, 1908.

Mallet articulated compound locomotives possess the following combination of distinguishing features: viz., two sets of driving-wheels, each having an independent set of frames, cylinders, pistons, crossheads, connecting rods, and valve gear, yet all under one boiler with a single firebox. The rear set of drivers is held in frames secured to the boiler and to the high-pressure cylinders, which are also fastened to the boiler, while the forward set of driving-wheels is held in frames which have a limited transverse motion about a pivot which joins them to the rear engine frames at a point midway between the two sets of driving-wheels. The forward set of drivers is connected to low-pressure cylinders which are not fastened to the boiler, but are hung to the forward section of frames, with which they swing transversely. The waist of the boiler is supported by sliding bearings which rest in turn on the forward section of frames, and spring stops are provided to prevent undue transverse motion.

Steam is conveyed through rigid pipes to the high-pressure cylinders, from which it in turn exhausts into a receiving pipe connecting the exhaust passages of the high-pressure cylinders with the steam passages of the low-pressure cylinders, after leaving which it passes through a flexible exhaust pipe to the exhaust nozzle in the smoke box and thence out of the stack in the usual manner. Hence this type of locomotive comprises two complete engines with but one boiler, and possesses the advantages of compounding, without entailing detrimental complications, as the forward engine is practically a duplicate of the rear one, except its cylinders and pistons are of sufficient size to compensate for the reduction in steam pressure between the high- and low-pressure cylinders. It is obvious that the high- and low-pressure engines should exert the same tractive power if the weights on both sets of drivers are equal, and if these weights are unequal the tractive power of the two engines should vary accordingly. Sometimes the number of drivers in the two engines differs. The forward engine is designed to swing

transversely in order to divide what would otherwise be an abnormally long, rigid wheelbase into two short rigid wheelbases, thus providing for the negotiation of curves. To further facilitate curving, or to support overhanging parts and steady the locomotive, leading and trailing pony trucks, or else carrying wheels, are sometimes used.

The articulated locomotive of today is not the result of a sudden conception, but rather the culmination of numerous attempts to build locomotives of this type, as evidenced by efforts dating from the pioneer days of American railroading. A review of the more important efforts should aid us in gaging the value of recent endeavors. This review

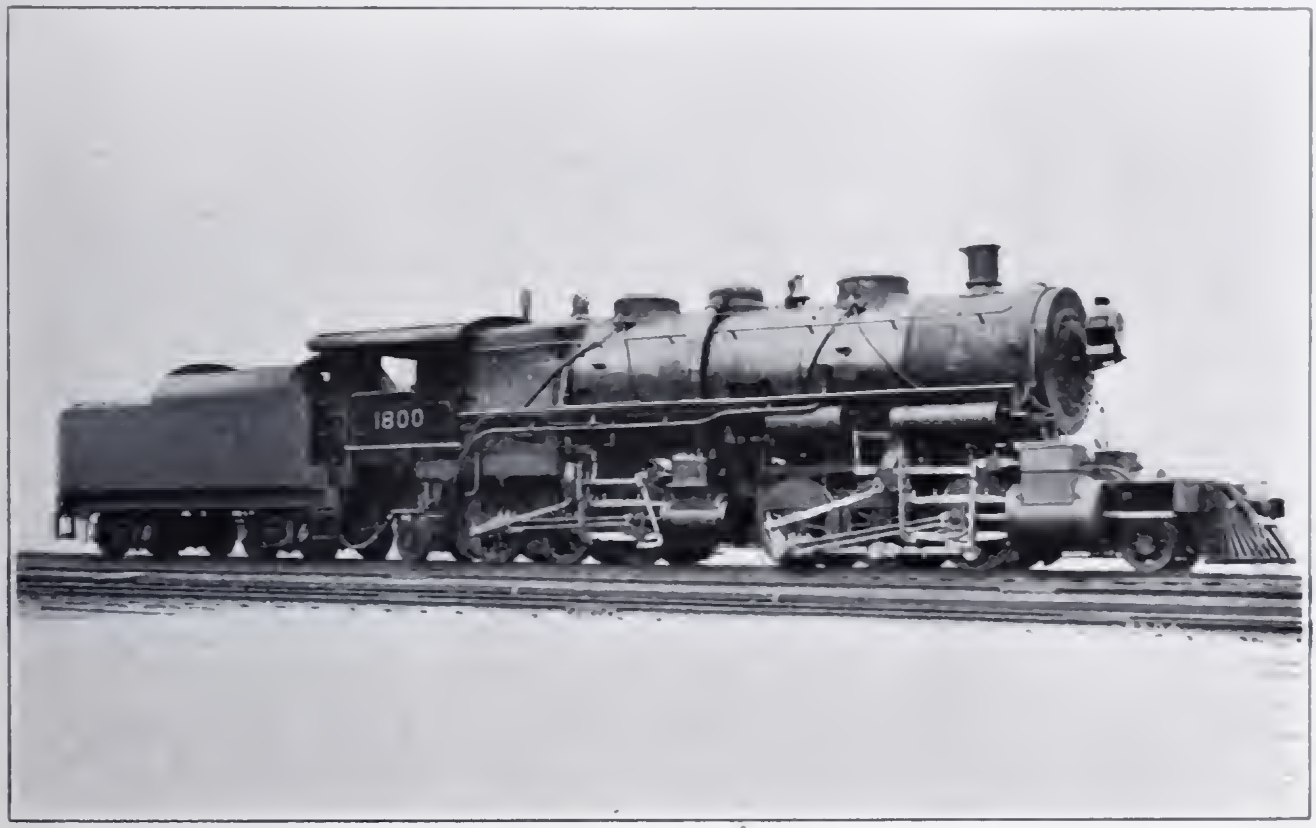


Fig. 1.—Mallet Type Locomotive in Pusher Service on Great Northern Railway.

will be confined to the better known designs of double truck and articulated locomotives; even mere mention of all the devices which have been employed to enable locomotives to traverse curves would consume too much time.

The "South Carolina," built in 1831 by the West Point Foundry for Horatio Allen, was the forerunner of the articulated system, yet this effort to distribute the weight of a locomotive over a number of wheels, and retain flexibility was too great a problem for that time. It was aimed to correct evils that could be avoided by simpler means, and caused some recognition of the fact that simplicity in design was of

paramount importance if locomotives were to be kept in working condition without unduly taxing the repair shops. Attention was then turned to improving roadbeds, strengthening tracks, and producing locomotives with a single pair of driving-wheels, and thus the articulated locomotive was relegated to temporary oblivion.

The basic factor controlling the hauling capacity of any locomotive depending on the frictional adhesion of the drivers to the rails is the total weight on driving-wheels, which is usually from four to four and one-half times the tractive power. Therefore an increase in tractive power demands corresponding increase in weight on drivers, and thus adds to the weight of the engine as a whole. It is understood that by "tractive power" we mean the total force exerted by the engine at the

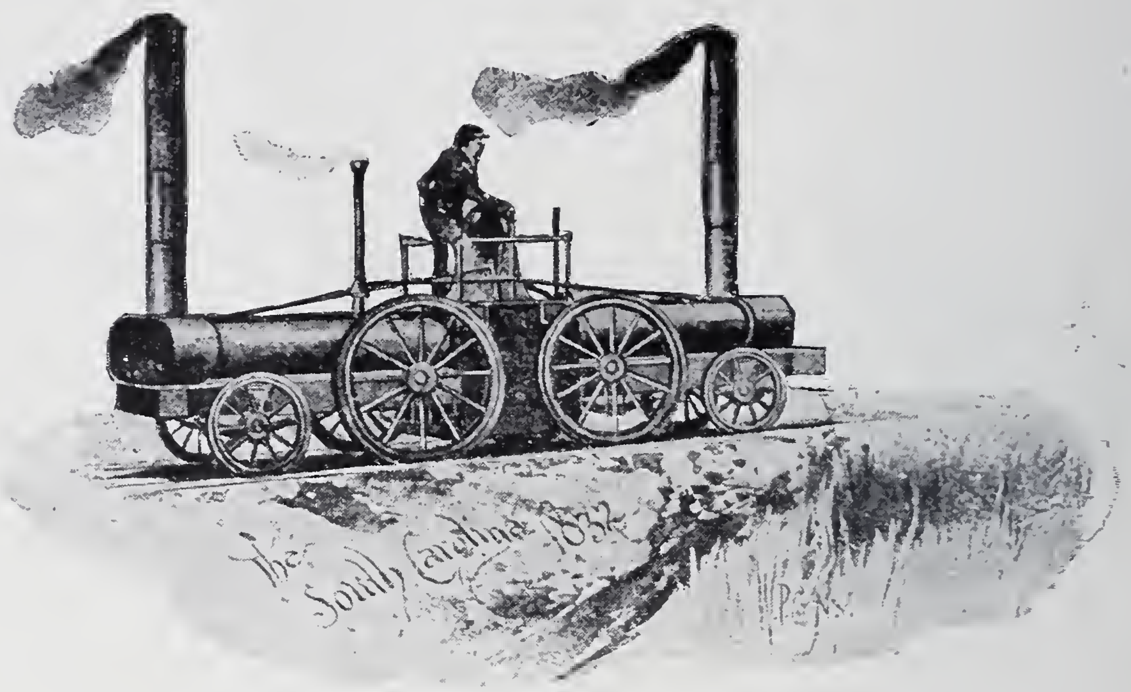


FIG. 2.—THE "SOUTH CAROLINA."

rails: it is the sum of the draw-bar pull plus the force absorbed in moving the engine. The weight on drivers multiplied by the coefficient of friction between driving-wheels and rails is the limit of effective tractive power, for, should this limit be exceeded, the drivers would slip on the rails and ineffectually revolve. The coefficient of friction, with wheels and rails in good condition, is usually between .2 and .25.

The "ratio of adhesion" is the ratio between tractive power and total weight on driving-wheels at the rails; thus if the latter is four or four and one-half times the former, the ratio of adhesion is 4 or $4\frac{1}{2}$, respectively. The ratio of adhesion should be at least the reciprocal of the coefficient of friction of the drivers at the rails.

Rails will support but a limited weight per wheel, so it follows that

when the tractive power required of a locomotive causes the weight per wheel to exceed the carrying capacity of the rails, additional wheels are necessary to subdivide the load. The addition of wheels in a continuous frame lengthens the rigid wheelbase of a locomotive, which can be done only to the extent allowed by curving.

To obtain flexibility, both on curves and on rough tracks, numerous devices have been tried and not a few adopted, including equalizing systems, two-, four-, and six-wheeled swing trucks, flexible beam trucks, journal boxes with extraordinary side play, tires without flanges, and now we again have the articulated engine problem before us.

Practically no attempt was made to improve Horatio Allen's design until over thirty years had elapsed, when an energetic Irish engineer named Robert F. Fairlie brought out the design of articulated locomotive which to this day bears his name. Fairlie, who was an earnest

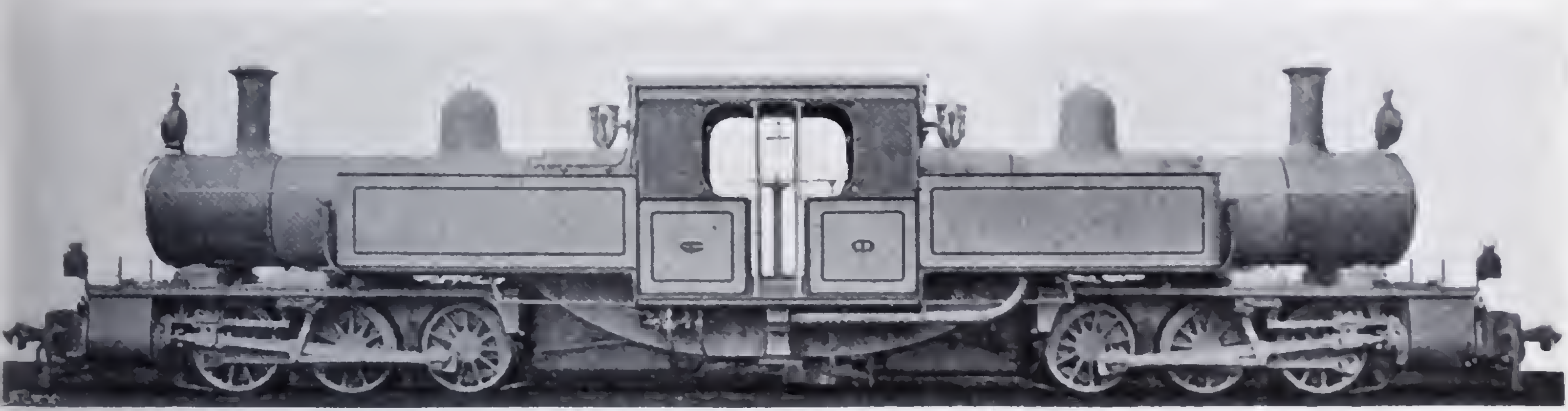


Fig. 3.—Fairlie Locomotive, Burma Railway.

advocate of narrow gage railroads, especially where road-building was expensive, had recourse to articulated locomotives to make transportation over such roads possible with minimum outlay for grading and reducing curvature. Fairlie "double enders," as they were familiarly called, may be likened to a combination of two independent locomotives, the boilers of which are joined together back to back (with space between for firing), by more or less elaborate framing, while the two engines, including separate frames, running gear, and cylinders, form independent trucks, free to swivel about the center pins on which the boilers rest. By imagining the substitution of steam for electric motors on both trucks of a double-truck electric car, we have a good example of the Fairlie system of running gear. These locomotives proved too flexible for other than slow service; thus their usefulness was confined to crooked mountain roads where speed was not a consideration.

Even under such conditions, when working hard, the component engines, owing to their short wheelbases, would oscillate or "nose" from side to side; the flexible steam pipes carrying steam at boiler pressure would continually leak, and when working to capacity the drivers of either

Fig. 4.—Mason-Fairlie Locomotive Built by Wm. Mason.

Fig. 5.—Mason-Fairlie Locomotive for Mexican Central Railway.

one or the other engine would often slip at critical times unless the ratio of adhesion was abnormal. Notwithstanding their shortcomings, however, so great was the demand for flexible locomotives that Fairlie type engines were introduced on a number of roads in several countries, and in many instances attained a reasonable degree of success. Modifi-

cations of this design have been made; sometimes the boilers have been joined, and in the "Meyer" locomotive only one boiler is used, while the arrangement of the double trucks is not materially different, except that the front and back engines are joined by a bar, and the front

Fig. 6.—Double Truck Compound Locomotive for Sinnemahoning Valley Railroad.

Fig. 7.—European Mallet Locomotive with Separate Tender.

engine cylinders are occasionally placed back instead of front of the drivers they operate. Some double-truck locomotives have been equipped with compound cylinders.

Efforts were made to introduce these engines in this country, principally by Wm. Mason, who at first built close to Fairlie's designs.

Later he built the "Mason-Fairlie" double-truck locomotives, having but one boiler and one set of driving-wheels which swiveled, also a rear truck which carried the water tank and fuel on the rear extension of the locomotive. These engines won many friends in their day.

As late as 1890 some Mason-Fairlie engines were built by the Baldwin Locomotive Works for the Mexican Central Railway.

A double-truck locomotive built by the Baldwin Locomotive Works for the Sinnemahoning Valley Railroad in 1892 was notable as being the first of that type in this country to be equipped with compound cylinders of the Vauclain system. While inheriting many of its predecessors' faults, it proved a step in the right direction.

In the mean time, Anatole Mallet, a Frenchman, who for years had endeavored to develop a successful compound locomotive, built, about 1888, the first of the articulated locomotives which became known as "Mallet articulated compound locomotives." At the expense of limiting curving ability somewhat, he inaugurated several important improvements which were destined to convert the articulated locomotive from a visionary scheme to a practical achievement. Instead of allowing the rear set of driving-wheels to swing about a center pin, he secured them laterally in line with the boiler, to which he permanently fastened the high-pressure cylinders, and delivered steam through fixed pipes, thus avoiding the use of one set of flexible steam and exhaust pipes. This arrangement provides what may be termed a substantial foundation to which the frames of the forward set of driving-wheels are hinged and avoids the lack of stability which is perhaps the most serious defect in the Fairlie system. The swing of the forward engine of a Mallet locomotive is limited to suit requirements, and the entire driving wheelbase of the locomotive is utilized to insure transverse stability.

A glance at Fig. 8 shows that in both the Fairlie and Mallet types pressure applied to the wrist pins tends to push the pins in the direction of the pressure, and, unless the engine is on the dead center, to rotate the drivers to which the pins are attached; whereas the reaction tends to move the cylinders and the frames to which they are fastened, in the opposite direction, which movement is necessarily in an arc about the center pin or pivot by which the frames are fastened to the boiler or to each other. If pistons on opposite sides of the engine worked in unison, the turning action on one side would counteract that of the other, but as the wrist pins on one side are ninety degrees in advance of those on the opposite side, it occurs that through alternate quarters of each

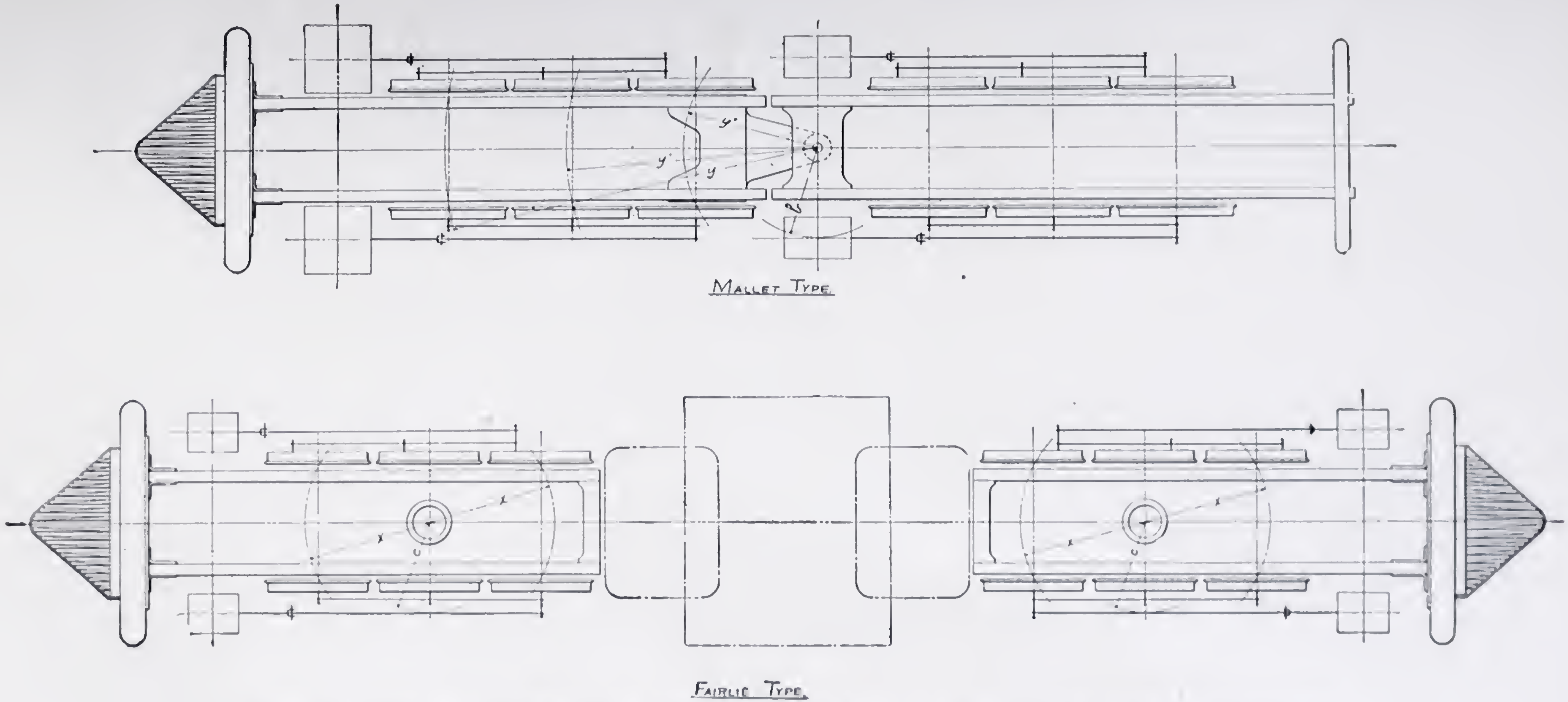


Fig. 8.—Plans of Frames and Running Gear, Mallet and Fairlie Type Locomotives.

revolution the pistons on the opposite sides move in contrary directions, and hence tend to move the individual engine about the center pin or pivot to which it is attached,—twice during each revolution of the drivers, once to the right and once to the left. All engines have clearance between the rails, wheel-flanges, journal boxes, wedges and gibs, and frames; therefore the engine is free to move transversely a distance equal to the sum of these clearances. Before the clearances are taken up, transverse motion, whether induced by steam pressure, or the movement of unbalanced parts, is resisted by inertia, and by the friction due to the weight on the journals and on the rails. The sum of the products of these resistances, multiplied by the radii ($y-y'-y''$ and $x-x$) of the arcs through which they act, is the total resistance of the engine to transverse motion; consequently it is evident with given weights per axles, and equal rigid wheelbases, this total resistance is greater in the Mallet type than in the Fairlie type, because of the longer average radius through which the resistance acts. In both types the reaction from the pressure on wrist pins is tangent to an arc with radius (b or c) equal to the distance from the center pin or pivot to the center of cylinder in which line the pressure acts, and the moment of turning is the product of the reaction by the radius of the arc through which it acts, and these moments are equal in engines of either type having the same total piston pressure and the same spread of cylinders.

It therefore follows that the Mallet type is more stable transversely than the Fairlie type locomotive, because with equal weight on drivers, and equally rigid wheelbases, it opposes a given turning moment by a greater moment of resistance to that turning.

Transverse stability is of great importance because if the moment of resistance is not sufficient to eliminate nosing, the engine will oscillate from side to side, causing the moving parts to wear rapidly, until the clearances are abnormal and the side motion too excessive for safety, or for economy in maintenance.

In Mallet locomotives no high-pressure steam is carried in flexible pipes, thus the leakage at joints is practically avoided. It has been found that low-pressure and exhaust pipes can be kept tight, whereas in Fairlie type engines it was practically impossible to prevent leakage from such pipes under high pressure. The importance of this improvement is the more keenly felt in cold climates, where any considerable leakage causes the engine to be enveloped in a cloud of condensed steam, and obstructs the view of the enginemen. It is to obtain this advantage that the low-pressure cylinders are made the movable

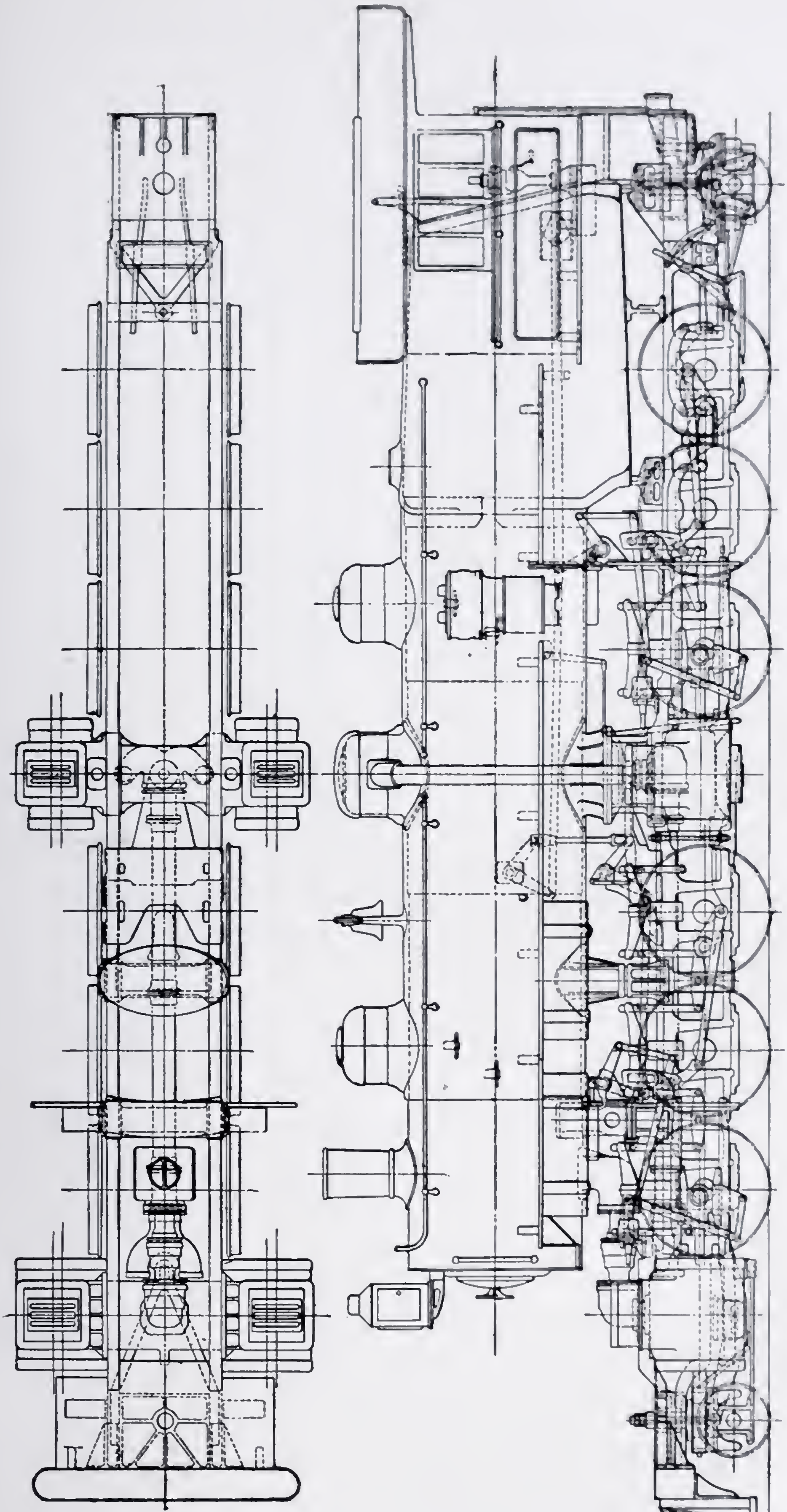


FIG. 9.—MALLET TYPE LOCOMOTIVE, SIDE ELEVATION.

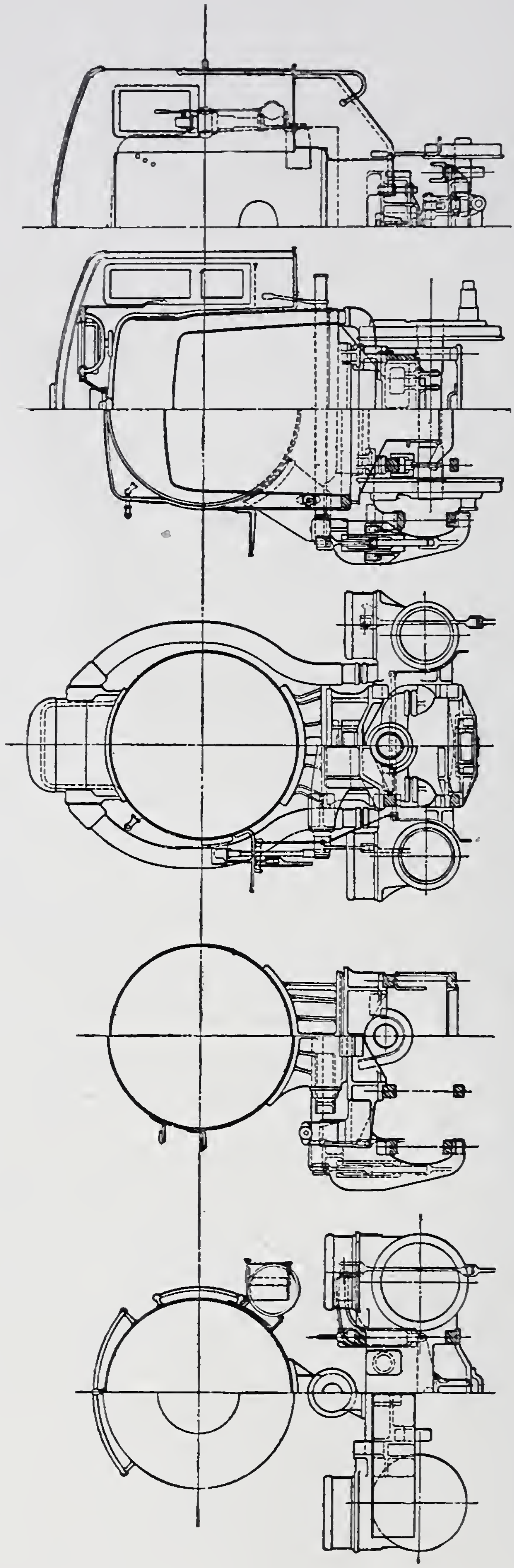


FIG. 10.—MALLET TYPE LOCOMOTIVE, CROSS-SECTIONS.

ones. Thus the application of the compound principle, in addition to effecting an economy in fuel, removes a very serious mechanical difficulty.

Another advantage derived from compounding is the elimination of a tendency to slip the drivers. Unless the ratio of adhesion is especially high, all articulated locomotives having separate engines fed by independent steam pipes give trouble, because when working to capacity it is found impossible to make both engines exert the same ratio of tractive power to weight on driving-wheels, hence either one engine or the other will frequently lose adhesion and slip. On grades this often results in stalling the train before the loss in pulling power can be recovered.

This trouble cannot occur with Mallet type locomotives, as in the event of slippage the locomotive immediately recovers itself, for the two engines depend, one upon the other for the distribution of the steam. Should the high-pressure engine slip, its exhaust would fill the receiving pipe faster than the low-pressure engine could relieve it, and the resulting back pressure on the high-pressure piston would prevent further slipping, and if the low-pressure engine should slip, it would exhaust the contents of the receiver until the pressure in the low-pressure cylinders was reduced sufficiently to stop the slipping. Any continuous slipping can only occur in both engines simultaneously, which can be corrected by the same means that might be necessary for regular types of locomotives under the same circumstances.

The motto "Nothing too much" seems to have been borne in mind by Mallet while endeavoring to produce a practical articulated locomotive. In addition to eliminating unecessary flexibility, he simplified matters further by replacing two small boilers by one large boiler; this not only reduced the integral number of parts comprising the boiler, but also provided one instead of two fires to be cared for. Mr. Mason also built articulated locomotives with one boiler, but in such cases only one set of drivers and cylinders was used, thus practically halving the capacity of a locomotive of given weight.

The boilers of Fairlie and Mason type, and other double-truck locomotives, rest on center pins, consequently the stability of these engines is not affected by curving; while, on the other hand, Mallet locomotives, having the boilers always in line with the rear set of drivers, are not so stable on sharp curves, as the forward set of drivers swing out of line with the center of the boiler to one side or the other. It is therefore apparent that curves could be sharp enough to cause the forward drivers

to swing from under the boiler sufficiently to destroy equilibrium. While this limitation does not apply to conditions generally prevailing on standard gage roads, it sometimes renders the Mallet type locomotive unsuitable for narrow gage roads where excessively sharp curves prevail.

To provide for curving, the boilers of all articulated locomotives must be placed high enough to allow the drivers to move transversely, hence the center of gravity of the boiler is necessarily higher than in types of locomotives in which the drivers do not move from side to side. This is also a point which applies to narrow gage roads particularly, and should be given due attention whenever articulated locomotives are under consideration.

Now that we have reviewed the evolution of the articulated locomotive, and compared its most prominent types, it is fitting that in turn a comparison be made with the common types of locomotives of more rigid construction, in order to ascertain if we are justified in reverting to the articulated engine.

It is almost an axiom that, barring limiting conditions, the simplest devices are best, and to this the locomotive is no exception. Had railroads been built for the convenience of those having to do with motive power, it is but logical to infer that the first articulated locomotive would have been the last. As conditions are, however, the design of a locomotive is often a compromise between what it should be and what it may be.

The restricting conditions include stability of roadbed, weight of rails, grades, curves, speed required, and amount of load to be hauled; also gage of track and the limits of height and width through which the train must pass; and seldom indeed does the designer escape being hampered thereby.

Modern ideas of economical railroad operation demand the use of the fewest possible number of trains to handle traffic, hence the size of trains on almost all roads is only limited by the hauling capacity of locomotives, the sizes of which, in turn, are restricted by the conditions already named.

Were it simply a question of providing for increased weight, heavier rails could be used and the stability of the permanent way improved, but as locomotives grow more powerful they must also increase in size, to provide for which, involves more serious problems. Each additional horsepower means more heating surface, with its relative addition to grate surface, and so the boiler must be larger, and there-

fore take up more room. The serious question is where to find the room.

This was a comparatively easy proposition when boilers were small in diameter and set so low that, taking a cross-section of the locomotive, the center of the boiler and points at either rail formed the boundary of an almost equilateral triangle. It is not so now, as in recent practice the height of such a triangle has grown to more than twice its base, and the boiler, instead of being entirely between the wheels, is, on account of its increased diameter, placed above them. On "standard" or 4′ 8½″ gage roads, boilers 7′ 0″ in diameter have been placed

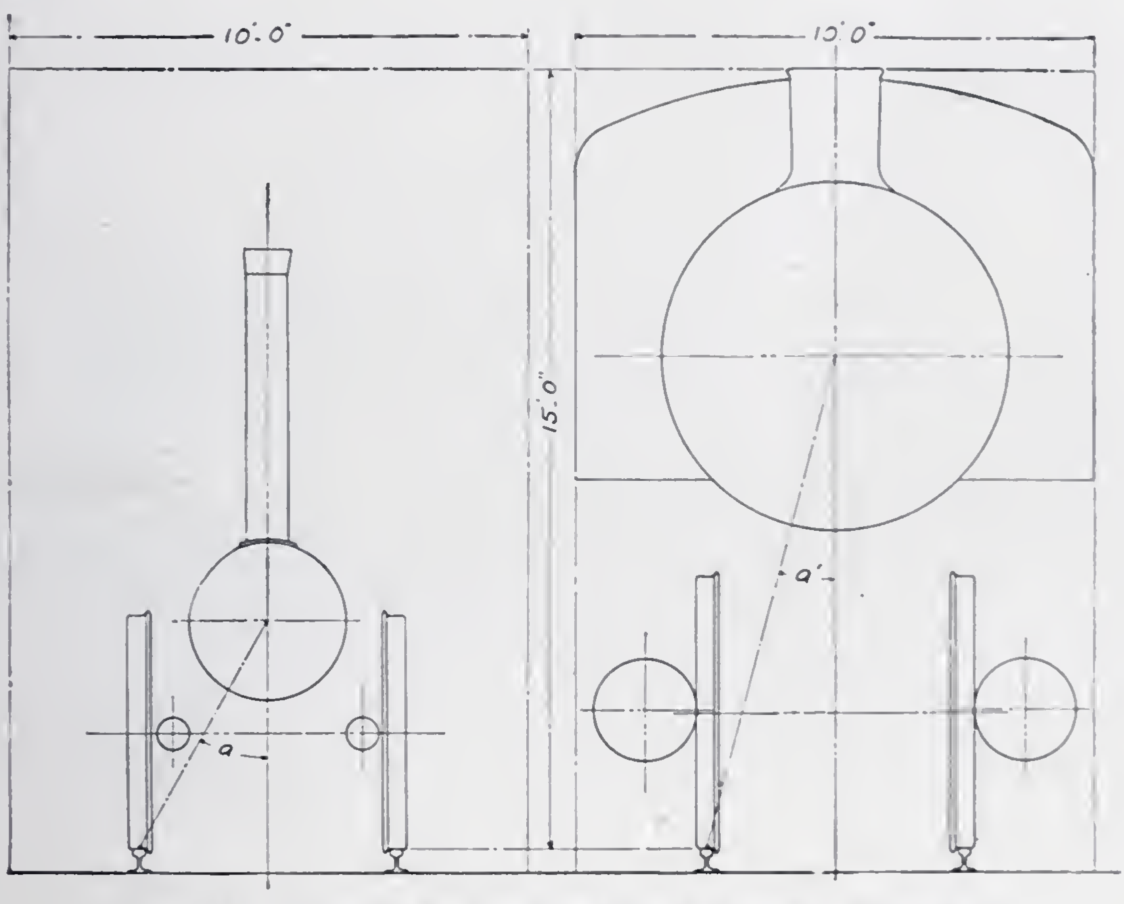


Fig. 11.—Diagram of Relative Boiler Heights.

10′ 0″ from top of rails to center of boiler, and the center of 42″ boilers on narrow gage roads of 2′ 0″ gage have been placed 5′ 0″ above the rails. Were lines drawn from the centers of boilers so located to the gage line at the rails, they would form angles with the perpendicular of less than 13 and 11½ degrees, respectively.

While the external limits of height and width may be modified somewhat, the effect of gravitation is constant, and limits the height a boiler may be safely placed above the rails, and it is generally conceded that the limit has practically been reached. As the diameter of the boiler is limited by the clearance to be obtained at a given height, it follows

that no material increase in boiler capacity can be obtained without lengthening the boiler, and in turn the engine, unless the standard gage of road is widened.

The gage of road, then, is the limiting factor which has remained constant and promises to so remain for some time to come. While it does, an increase in the power and size of locomotives means also an increase in their length, and if the locomotives are of the common rigid frame type, a corresponding decrease in their flexibility and curving ability.

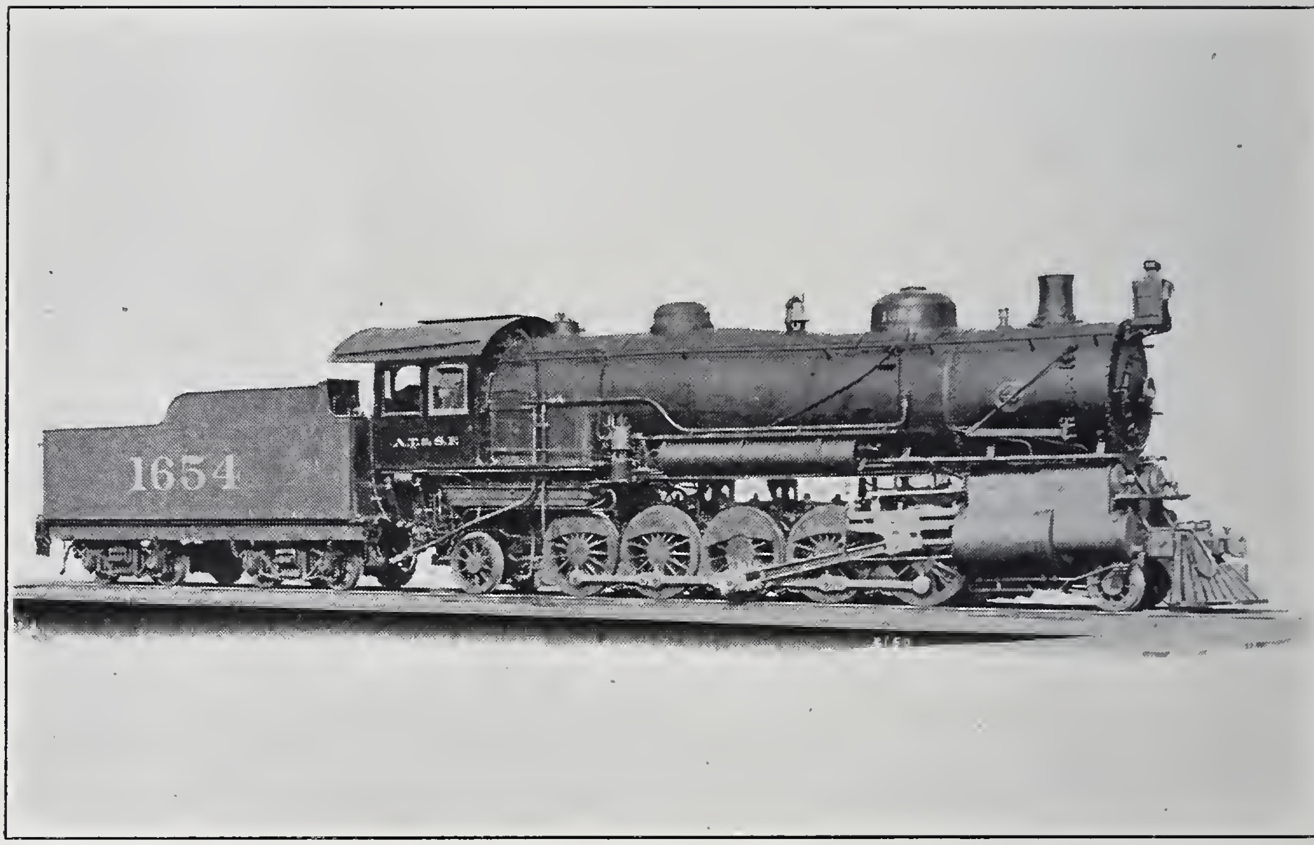


FIG. 12.—"SANTE FE" TYPE LOCOMOTIVES, FOR ATCHISON, TOPEKA AND SANTE FE RAILWAY.

The heaviest rigid frame locomotives in the world are of the "Sante Fe" type, with a total weight in working order of 287,000 pounds, of which 234,000 pounds are on the driving-wheels. These engines, of which over 150 have been built by the Baldwin Locomotive Works for the Atchison, Topeka and Sante Fe Railroad, are fitting examples of what can be done along conventional lines, and therefore may be properly compared with locomotives of the Mallet type. Notwithstanding they are close-coupled, their rigid wheelbase is 19′ 9″, while the Mallet type locomotives, having six pairs of driving-wheels, bearing increased weight, have a rigid wheelbase of only 10′ 0″, thus gaining

the advantage in flexibility which enables them to curve more easily, with reduced wear on driving-wheel flanges and with less damage to tracks. The articulated locomotive also divides the total work between two systems of machinery, thus cutting in half the strain on any one part, which allows the individual parts to be made lighter, and adds to the convenience with which repairs can be made. The simplicity of the compound feature has already been referred to.

The "Sante Fe" type locomotives are doing splendid work, but they seem to be close to the practical limit of size for rigid frame engines;

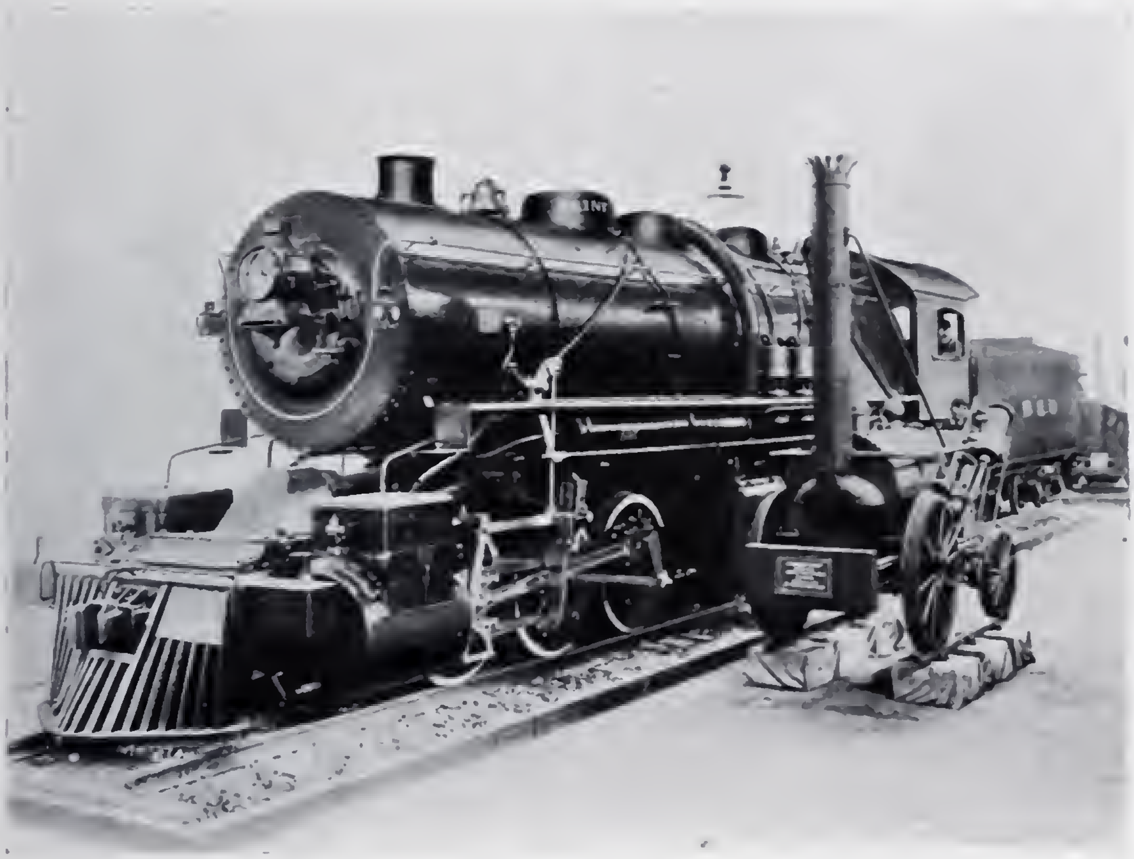


Fig. 13.—First Mallet Type Locomotive Built in this Country, for Baltimore and Ohio R. R.

therefore the increased number of parts incident to locomotives of the Mallet type is a necessity we have not learned to avoid, if larger engines are to be built for standard gage roads.

Some account of the advent and use, in this country, of the Mallet type locomotives will doubtless assist us in estimating the value of their claim for favorable consideration.

The honor of building the first of these engines for an American road falls to the American Locomotive Company, who, in 1904, constructed for the Baltimore and Ohio Railroad Company a twelve-wheel Mallet type locomotive, having three pairs of drivers in each system, and a

weight in working order of 334,000 pounds, all on drivers. This locomotive was exhibited at the Louisiana Purchase Exposition and then placed in pushing service near Rockwood Junction, where its performance has attracted considerable attention.

During the same year the Baldwin Locomotive Works built metre gage Mallet type locomotives for the American Railroad of Porto Rico, which weighed 106,000 pounds, all on driving-wheels, of which there were two groups, of three pairs each. Aside from the unusual weight

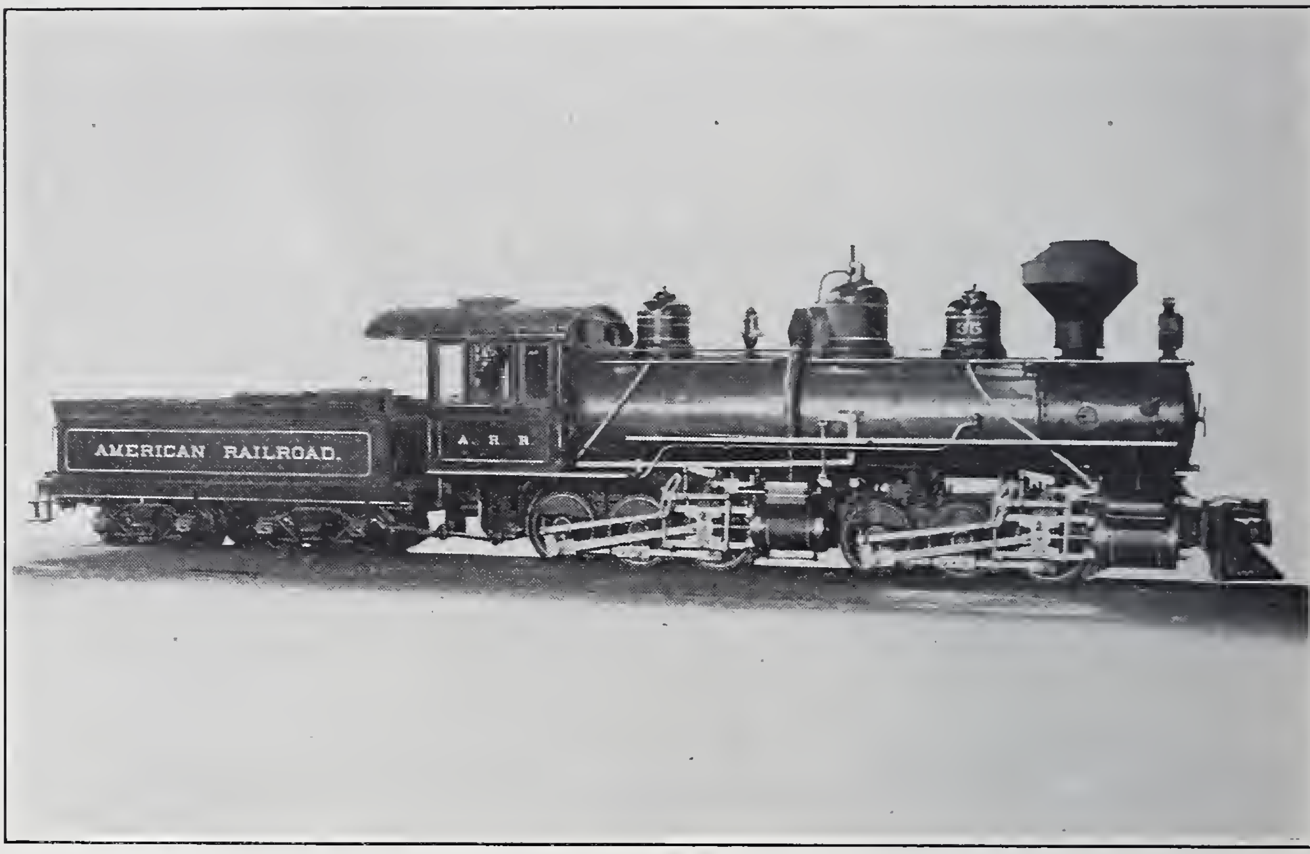


FIG. 14.—NARROW GAGE MALLET TYPE LOCOMOTIVE FOR AMERICAN R. R. OF PORTO RICO.

and hauling capacity for narrow gage service, these engines were not required to meet exceptional conditions.

About a year later two locomotives of similar type and size, but for 3′ 6″ gage, were built for the Guayaquil and Quito Railway in Ecuador, where both grades and curves are numerous and severe.

Last year the American Locomotive Company built several Mallet locomotives for the Erie Railroad. They are the heaviest engines ever built, their weight being 409,000 pounds, all on driving-wheels, of which there are two groups, of four pairs each.

The introduction of Mallet type locomotives in American service on a scale of sufficient magnitude to demonstrate their capabilities is

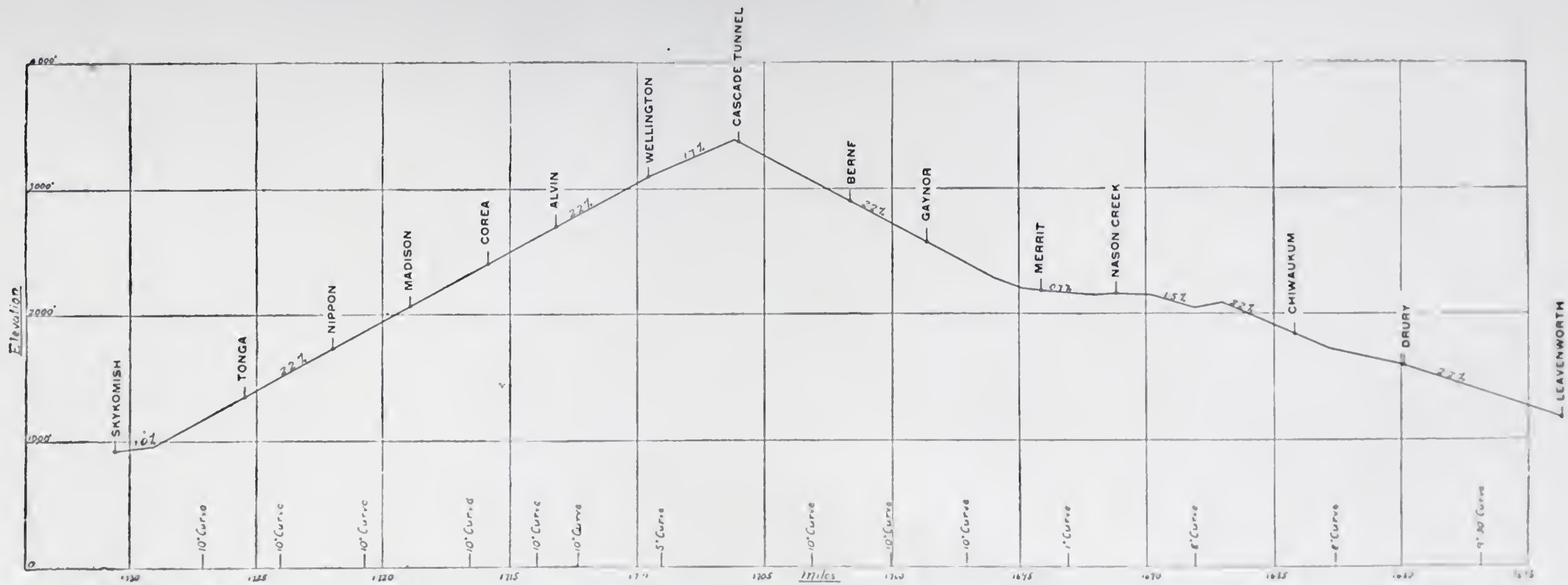


FIG. 15.—PROFILE, GREAT NORTHERN RAILWAY, INCLUDING GRADE BETWEEN LEAVENWORTH AND CASCADE TUNNEL.

due to the foresight of Mr. James J. Hill, who believed the use of heavy articulated locomotives would relieve the congestion of traffic on the mountain divisions of the Great Northern and Northern Pacific Railways, and furthermore backed his belief by ordering that five of these engines be built. The designs were carefully prepared by the Baldwin Locomotive Works, in consultation with Mr. G. H. Emerson, S. M. P. of the Great Northern Railway, on which the first locomotives were to be used on grades of 2.2 per cent. in conjunction with curves of 10 degrees. The engines were to push trains up the grade and back down for another load without turning, and the question as to how their

Fig. 16.—Recent Consolidation Locomotives, Great Northern Railway.

vast weight could be made to curve without excessive flange wear was a problem the solution of which caused much thought and discussion.

The question was solved by providing leading and trailing wheels in radial trucks, such as are used on rigid frame road locomotives. This feature of construction proved successful, as notwithstanding the weight of these engines, which is 355,000 pounds, of which 316,000 pounds is on the drivers, they are remarkably easy on flanges and tracks. In the fall of 1906 these locomotives were placed in service between Leavenworth and Cascade Tunnel, a distance of about 32 miles. Their rating on a 2.2 per cent. grade is 800 tons of cars and lading, and their

usual duty is to take, with a leading Consolidation locomotive, a load averaging 1200 tons in weight, exclusive of engines and tenders. As the Mallet locomotives weigh, with 8000 gallon tenders, about 252 tons, and the Consolidations, with 6000 gallon tenders, weigh about 157 tons, the weight of the entire train is approximately 1614 tons, of which the Mallet engines handle 1057 tons, or 65.5 per cent. of the total.

The saving in fuel these engines effect is remarkable. Careful tests conducted under the direction of Mr. Emerson show the unusual re-

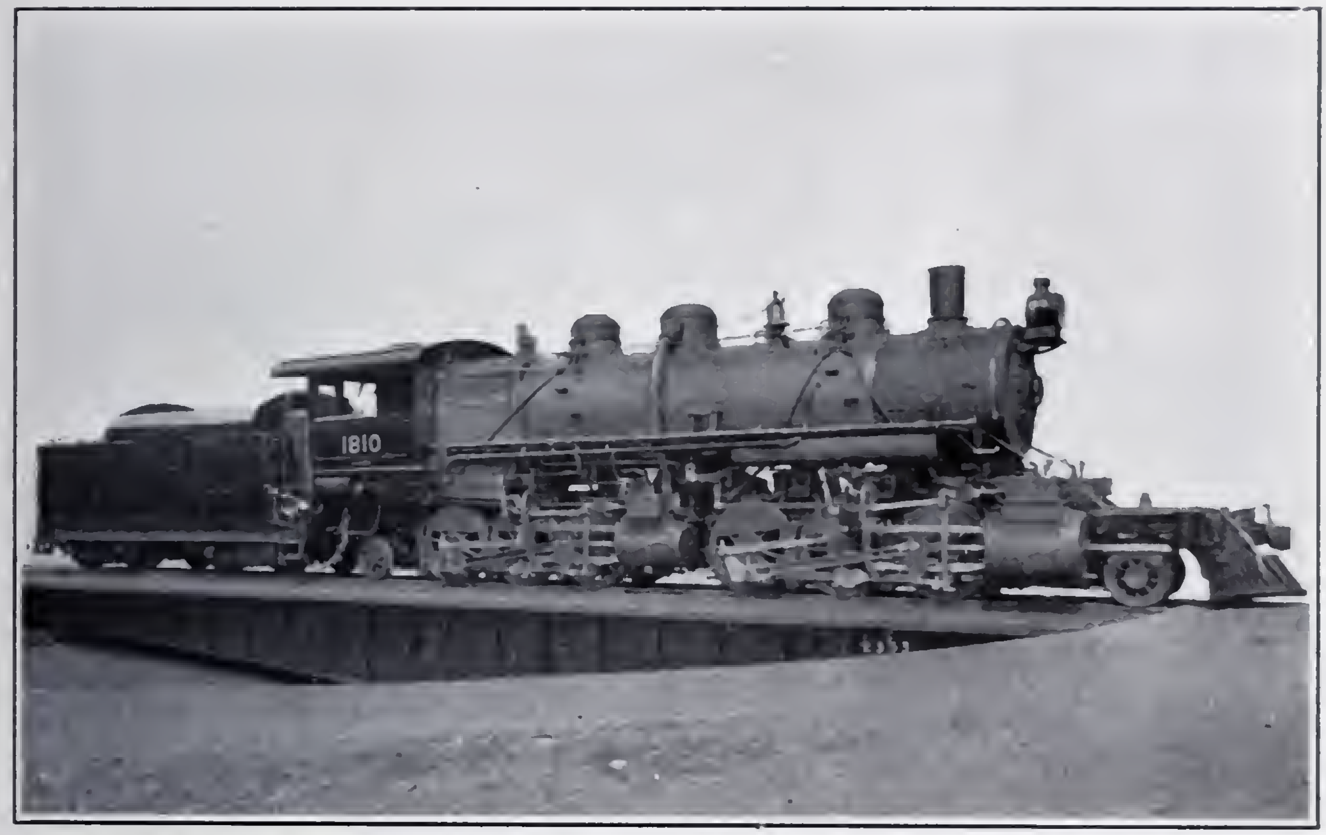


Fig. 17.—Mallet Type Locomotives in Road Service on Great Northern Railway.

duction in the amount of coal used per ton mile of 46 per cent., as compared with the coal required for the single expansion Consolidation locomotives, engaged in the same work.

From the trials of the first locomotives it was found, notwithstanding prevailing ideas to the contrary, that Mallet type locomotives, in addition to heavy slow work, could be used to advantage for heavy hauling in road service. In consequence, twenty-five lighter Mallet locomotives were placed in service between Leavenworth and Spokane, a distance of 197 miles, in which many grades of 1 per cent. occur. These engines were also built by the Baldwin Locomotive Works and

followed the same general design as the larger locomotives. They have twelve drivers divided in two groups, front and rear trailing wheels, weigh in working order 302,000 pounds with 263,000 pounds on drivers, and with 8000 gallon tenders, make a total weight of 231 tons. They easily haul 1450 tons of cars and lading on the 1 per cent. grades, and where lighter grades permit, attain speeds of 25 to 30 miles per hour, thus making the same time as Consolidation locomotives in the same work, but with the advantage of doing more work and doing it cheaper per ton-mile.

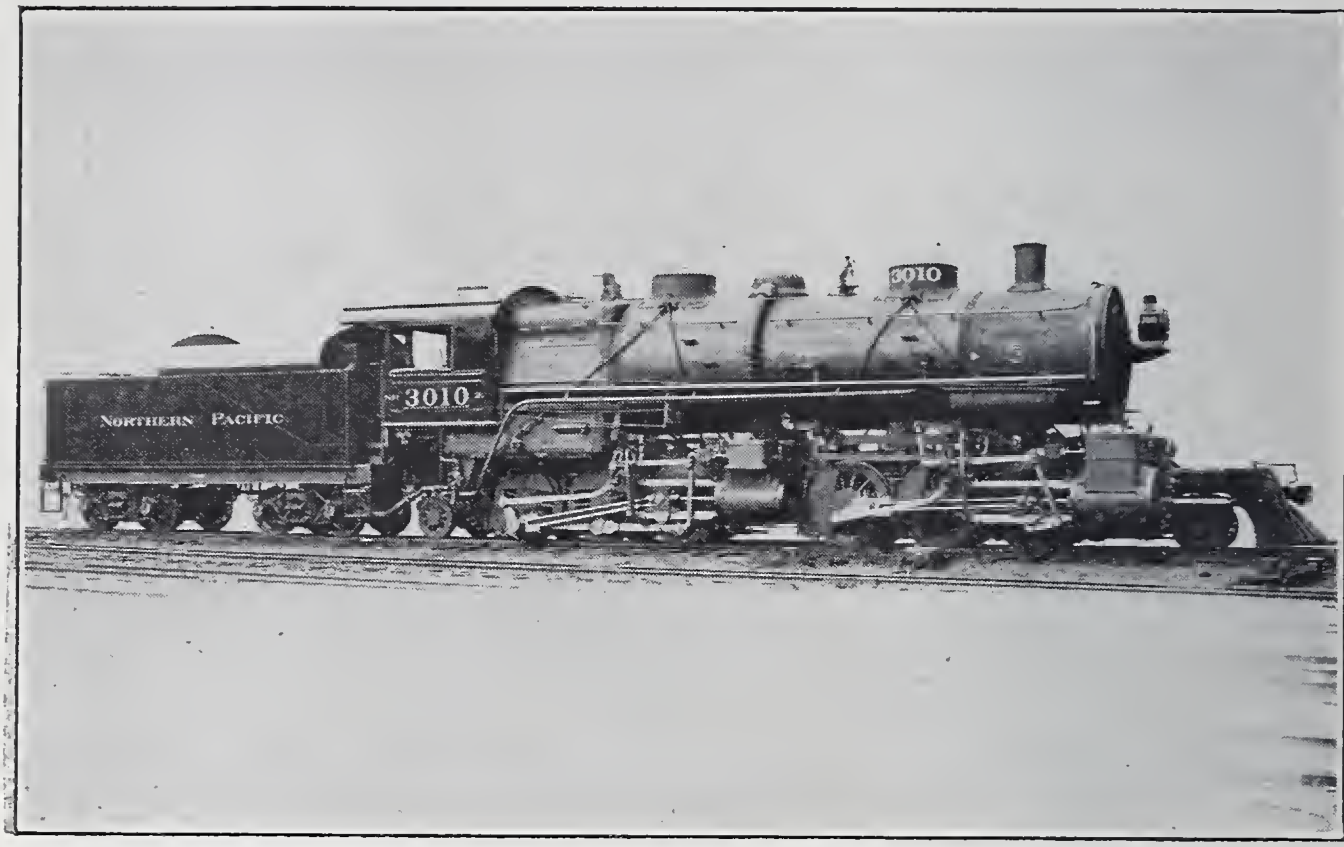


FIG. 18.—MALLET TYPE LOCOMOTIVES FOR NORTHERN PACIFIC RAILWAY.

Investigation by the Great Northern Railroad Company shows an average saving of 31½ per cent. per ton-mile in favor of the Mallet locomotive's coal consumption, as compared with that of the Consolidation engines in similar road service. This is not based upon the records of a few tests, but upon accounts covering a period of four months, while both classes of locomotives were working under normal conditions. Five months' records show the average cost of repairs to be 9 cents per mile for the Mallet type and 7½ cents for the Consolidation locomotives, and when the relative weights of the engines are considered, this means a saving approximating 19 per cent.

Comparisons are not available of the repairs to heavy Mallet locomotives with those of the other helper engines.

While the economies in fuel and maintenance are of consequence, they are overshadowed by the importance of increasing the efficiency of the railroad system as a whole, through reducing the number of locomotives on crowded divisions, thus allowing a minimum of train movements and simplifying the work of the operating departments.

A further economy is obtained because of the reduced number of train crews, but there is a small offset to this saving, as some increase

Fig. 19.—Profile Northern Pacific Ry., Including Grade between Livingston and Bozeman Pass.

in pay is allowed to the men on the engines, unless a fireman's helper is employed.

The convincing proof of the results obtained, however, is shown by the fact that twenty additional road locomotives are now being finished by the Baldwin Locomotive Works for this road, which are to be followed by twenty more heavy Mallet type locomotives, so before the end of this year the Great Northern Railway will have in service seventy of these locomotives.

One of the first heavy Mallets was borrowed by the Northern Pacific Railway for trial between Livingston and Bozeman Pass Tunnel, a distance of 12½ miles, with maximum grade of 2.2 per cent., and curves of from 1 to 8 degrees. These trials were conducted by Mr. W. L. Kinsell, M. E., for the railway company, and resulted in the Baldwin Loco-

motive Works building sixteen locomotives practically duplicates of the heavy Mallet type engines of the Great Northern Railway. These engines, which are now in service, weigh 351,000 pounds in working order, with 313,500 pounds on drivers, and with 8000 gallon tenders weigh 250 tons. They act as pushers behind trains pulled by either Mikado type or Consolidation locomotives, weighing respectively 258,000 and 186,000 pounds, with 203,000 and 166,000 pounds on drivers. The former, with 8000 gallon tenders, weigh 209, and the latter, with 5500 gallon tenders, weigh 149 tons. From information given by Mr. Wm. Moir, S. M. P., and Mr. Kinsell, the rating on the heaviest grades is found to be 850 tons of cars and lading for the Mallet locomotives, 600 and 500 tons

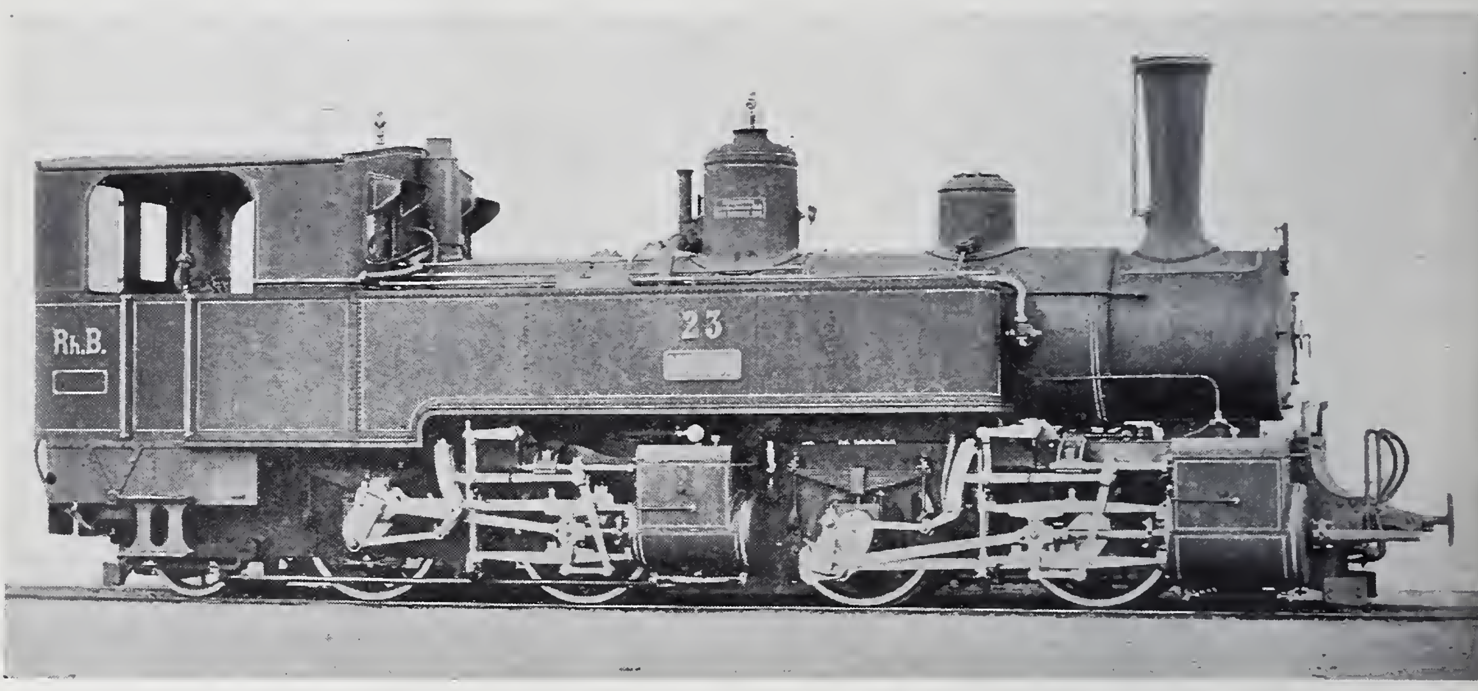


FIG. 20.—EUROPEAN MALLET TYPE TANK LOCOMOTIVE.

respectively for the Mikado and Consolidation locomotives. In actual practice the Mallet engines usually handle from 60 to 65 per cent. of the total tonnage. No accurate comparative tests have yet been made covering fuel consumption or repairs, as prevailing conditions have not warranted using the Mallet locomotives to their capacity for any length of time since their installation in the fall of 1907, but we have no reason to expect results materially different from those obtained by their predecessors on the Great Northern Railway.

Mr. Mallet designed his first locomotives to meet conditions prevailing in Europe, and you will note that the features common to European practice are carried out in his designs. These locomotives are now built by most of the prominent European locomotive builders.

In the majority of instances, the smaller European Mallet engines have been provided with side tanks, so that the locomotives have not required a separate tender. This arrangement has the advantage of utilizing all the weight possible on the driving-wheels, considering

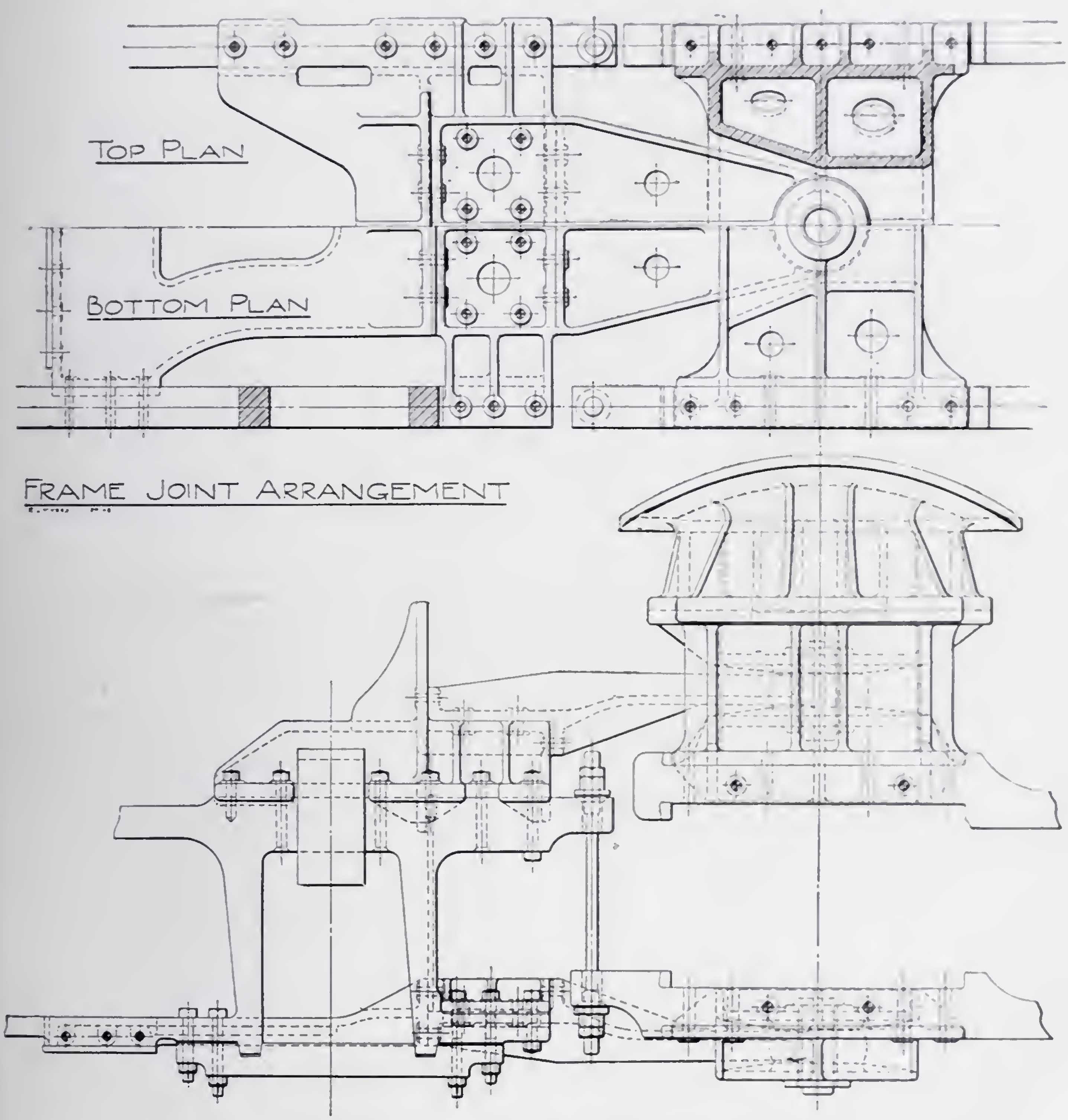


FIG. 21.—FRAME JOINT ARRANGEMENT.

the engine and tender as a whole. The larger engines, however, often have separate tenders. The weights of European Mallet engines usually range from 25 to about 110 tons, thus the problem of applying this system to American practice involves considerable ingenuity in devising ways and means of providing for the increased size of the

units. When it is considered that the heaviest European Mallet type locomotives weigh something less than half as much as the heaviest engines of that type in this country, it will be realized that strength of materials, distribution of strains, and adaptation of parts to a lim-

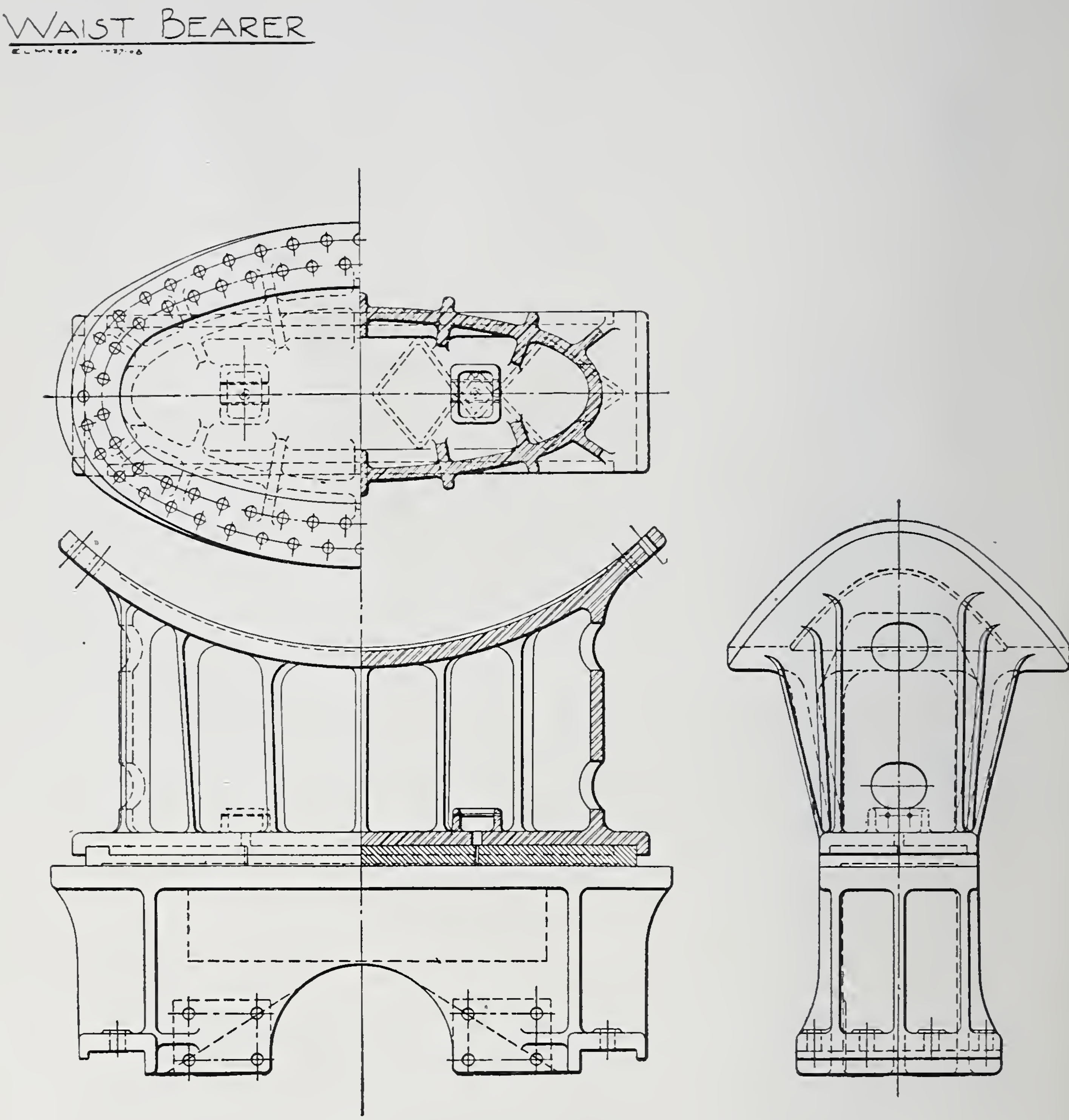


Fig. 22.—Waist Bearer, Supporting Front End of Boiler.

ited space are not simple problems, so while we are indebted to Europe for the Mallet design, we in this country have been obliged to overcome difficulties at every turn in order to adapt them to our service.

Some of the mechanical details of the Great Northern and Northern Pacific Mallets are worthy of notice.

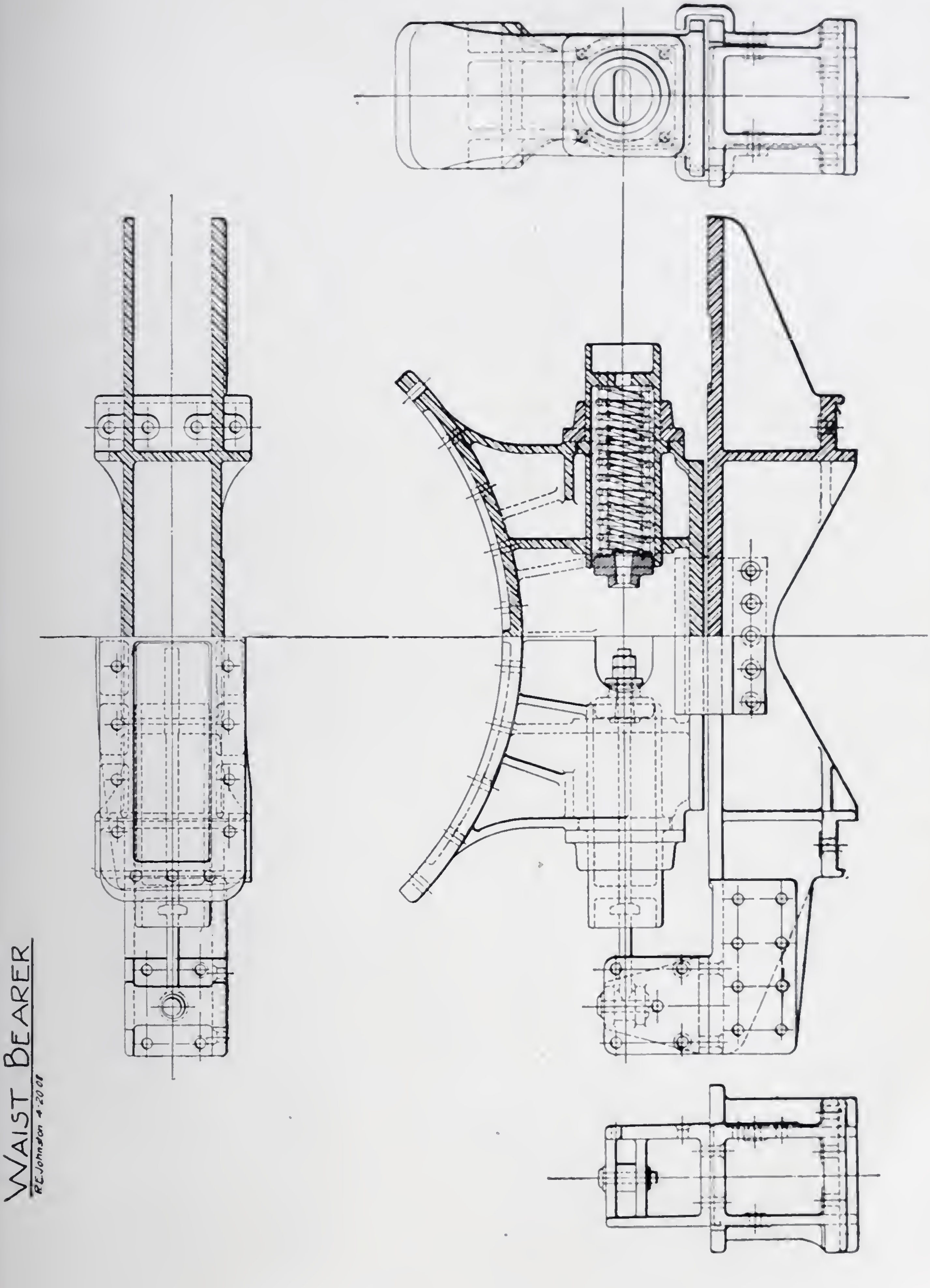


Fig. 23.—Thrust Springs and Bearings.

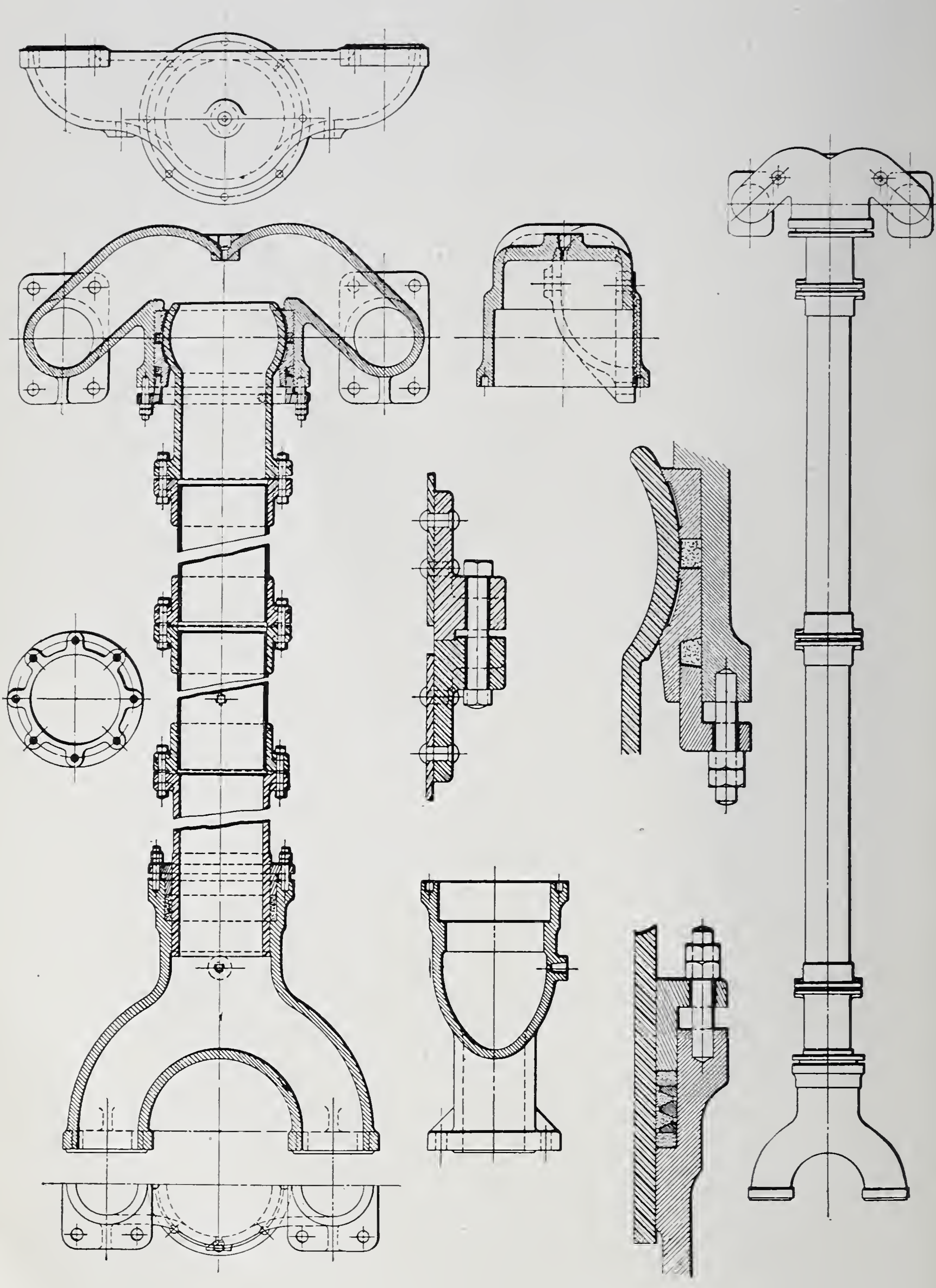


Fig. 24.—Receiving Pipe.

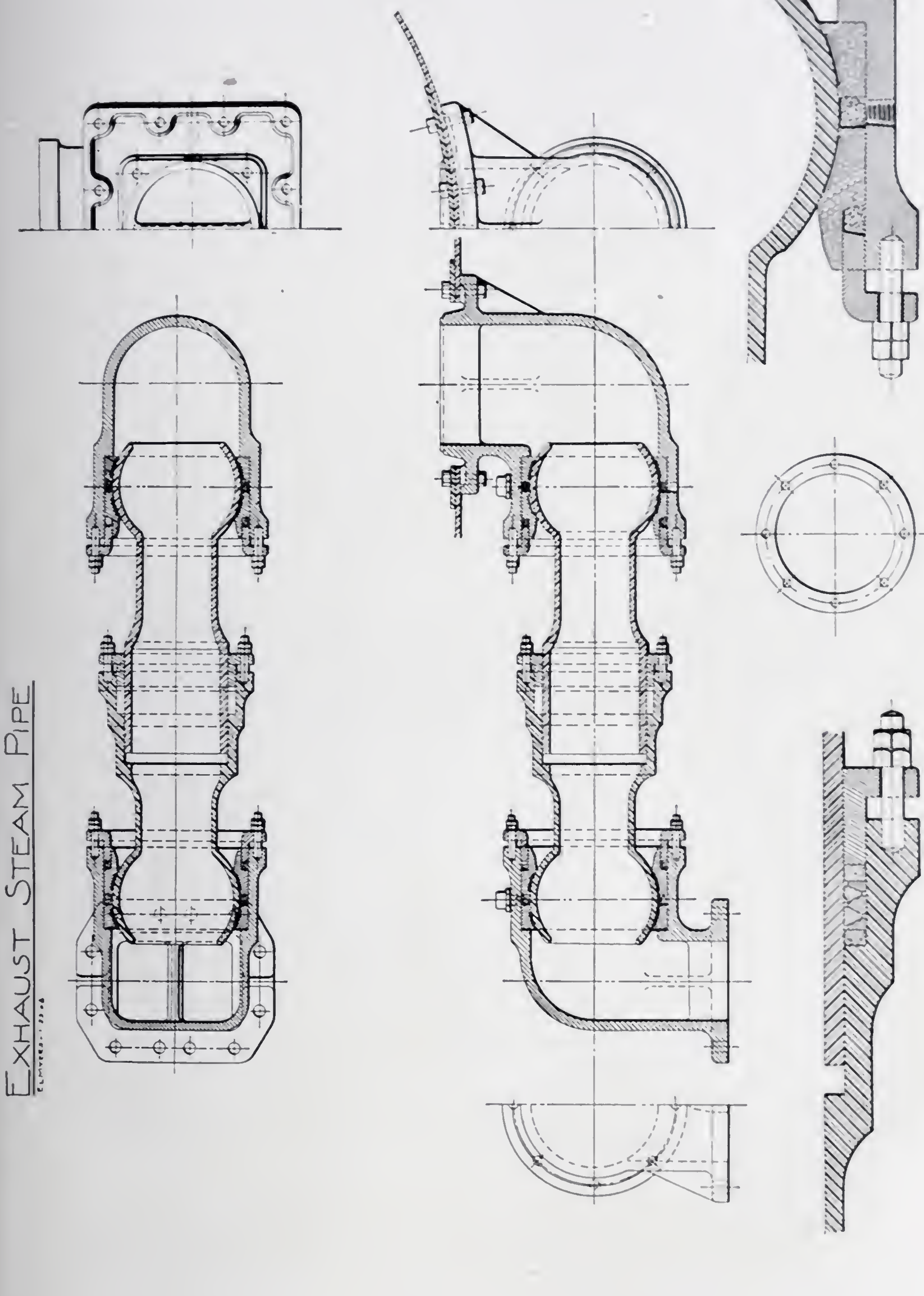


Fig. 25.—Exhaust Steam Pipe.

The hinge connecting the two engines, although double, and attached to both upper and lower bars of frames, is a very simple device, which must necessarily be strong and firmly attached.

The bearing slides on which the forward end of the boiler rests are of cast-steel, the upper half being riveted to the boiler, and the lower half bolted to the frame of the low-pressure engine; the bearing pieces are of cast-iron.

Thrust springs and their bearings are placed ahead of the bearing slides to regulate the slide movement of the forward engine. These bearings are not intended to support the boiler.

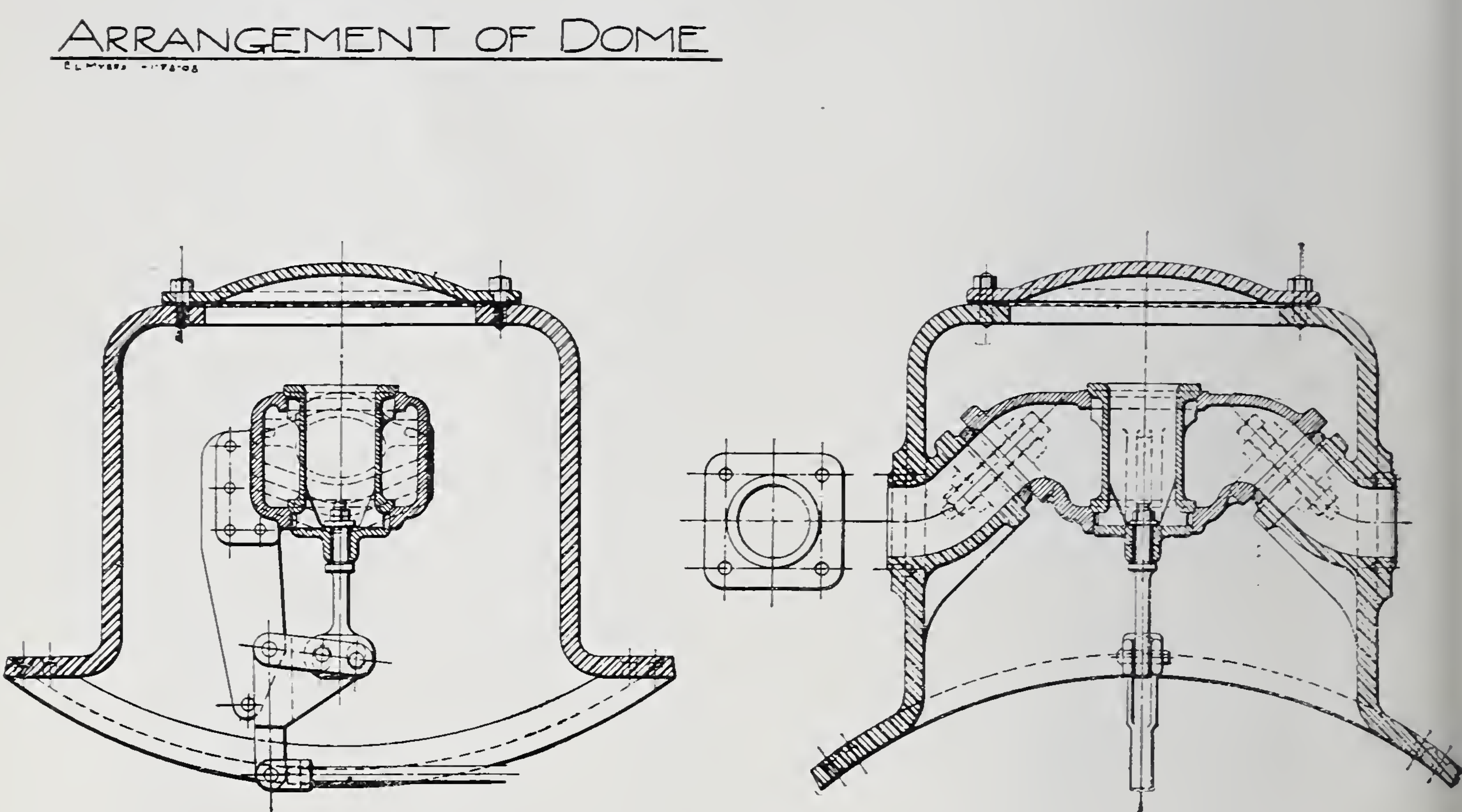


Fig. 26.—Cast Steel Dome.

The receiving pipe is easy of access for adjustment and packing, and is not at all complicated, having but one ball and one sliding joint. The exhaust pipe is similar in construction, but has one additional ball joint. These joints require but little attention in either pipe, as they only carry low-pressure or exhaust steam, and the tendency to leak is small.

In order to save room, and restrict the height of the locomotives within certain limits, an ingenious combination of throttle and cast-steel dome has been devised. The valve box rests on elbows leading to the outside steam pipes.

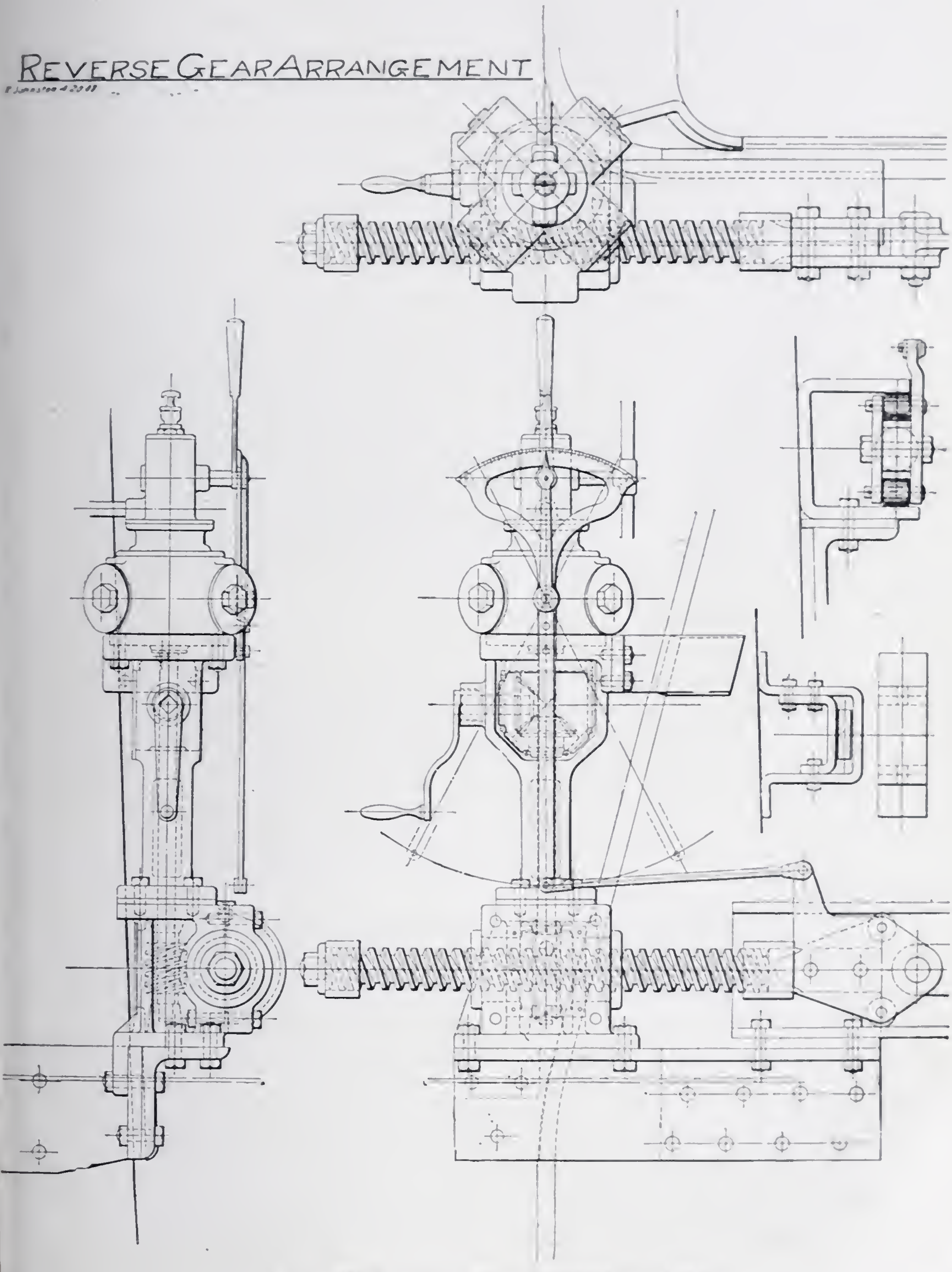


FIG. 27.—MCCARROLL AIR REVERSING GEAR.

A McCarroll air reverse is used so that an engineer can easily handle the locomotive and adjust the cut-off without physical effort. The valve motions of both engines are connected to one reversing screw, which is operated by an air engine. Provision is made for reversing by hand, if for any reason air pressure is unavailable.

The steam chest valves are operated by the Walschærts' valve gear, which has become so common in this country as to require no special comment. Its use is particularly advantageous on this type of locomotive, because the eccentrics for an inside valve motion could not be placed under the firebox, which is directly over the rear engine.

No complicated starting valves are required for these locomotives; if necessary, steam can be admitted to the low-pressure cylinders through the receiving pipe, to which it is fed through a $1\frac{1}{4}$ inch pipe. The supply of steam is regulated by an ordinary pattern of valve or cock. It is, of course, important that the steam should be shut off as soon as the exhaust from the high-pressure cylinders is effective.

Cylinder lubrication is provided by a four-feed lubricator, with pipes leading to the high-pressure steam chests in the usual manner, and to the low-pressure steam chests so that the pipes will move with the forward engine. It was found inadvisable to attempt to lubricate the low-pressure cylinders through the receiving pipe.

The tractive power of a Mallet type locomotive is figured in the same manner as for cross-compound two-cylinder locomotives, except the result is doubled because of twice as many cylinders. The formula follows:

$$\frac{C^2 \times S \times \frac{4}{3} P}{D} = T$$

where

C = diameter of high-pressure cylinders, in inches.
S = stroke of high-pressure cylinders, in inches.
D = diameter of driving-wheels, in inches.
P = boiler steam pressure in pounds.
T = tractive power in pounds.

The use of this formula is obviously based upon equal average total mean effective pressures on both high- and low-pressure pistons. In order to obtain this equality, the ratio of the area of the high- to the low-pressure pistons should be as 1 is to 2.4, with an allowable variation either way of .1.

We have now in a general way analyzed the design of the Mallet type articulated locomotives, compared them with other articulated locomotives, and with engines with rigid frames; we have also reviewed

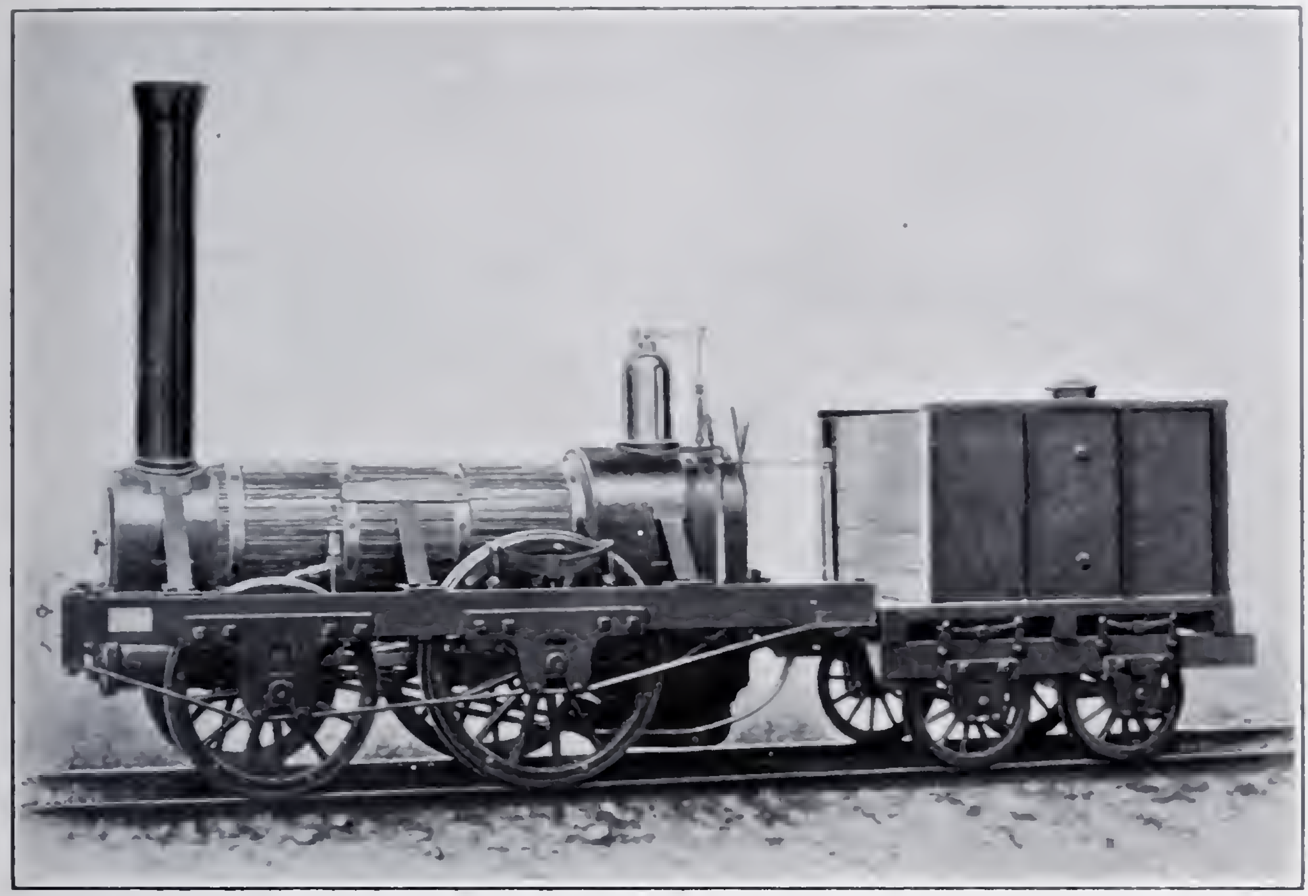


Fig. 28.—Old Ironsides—1831.

Fig. 29.—Recent Shipment from Baldwin Locomotive Works to Great Northern Railway—1908.

GENERAL DIMENSIONS OF GREAT NORTHERN AND NORTHERN PACIFIC LOCOMOTIVES.

	Great Northern.			Northern Pacific.		
B. L. W. Class	16-$\frac{37}{60}$ $\frac{1}{4}$ D D	16-$\frac{34}{56}$ $\frac{1}{4}$ D D	10-34 E	16-$\frac{37}{60}$ $\frac{1}{4}$ D D	12-42 $\frac{1}{4}$ E	10-$\frac{40}{62}$ E
Company's Class	L-1	L-2	F 8	——	W	Y
Type	2-6-6-2	2-6-6-2	2-8-0	2-6-6-2	2-8-2	2-8-0
"	Mallet	Mallet	Consolidation	Mallet	Mikado	Consolidation
Cylinders H. P.	$21\frac{1}{2}''$ x 32″	20″ x 30″	20″ x 32″	$21\frac{1}{2}''$ x 32″	24″ x 30″	23″ x 34″
" L. P.	33″ x 32″	31″ x 30″	None	33″ x 32″	None	34″ x 34″
Diameter Drivers	55″	55″	55″	55″	63″	54″
Boiler Diameter	84″	72″	$74\frac{1}{8}''$	84″	$75\frac{3}{4}''$	$72\frac{1}{8}''$
" Type	Belpaire	Belpaire	Belpaire	Belpaire	Wagon top with Com. Cham.	Wagon top
Working Pressure	200 lbs.	210 lbs.	210 lbs.	200 lbs.	200 lbs.	200 lbs.
Firebox	117″ x 96″	$116\frac{1}{8}''$ x $66\frac{1}{4}''$	118″ x $72\frac{1}{4}''$	117″ x 96″	96″ x 65″	120″ x 42″
Tubes, Diameter	$2\frac{1}{4}''$	$2\frac{1}{4}''$	2″	$2\frac{1}{4}''$	2″	$2\frac{1}{4}''$
" Length	21′ 0″	21′ 0″	14′ 8″	21′ 0″	16′ 6″	14′ 0″
" Number	441	301	331	437	272	330
Heating Surface, Tubes	5,433 sq. ft.	3,708 sq. ft.	2,572 sq. ft.	5,383 sq. ft.	3,214 sq. ft.	2,705 sq. ft.
" " Firebox	225 sq. ft.	198 sq. ft.	195 sq. ft.	225 sq. ft.	259 sq. ft.	221 sq. ft.
" " Total	5,658 sq. ft.	3,906 sq. ft.	2,767 sq. ft.	5,608 sq. ft.	3,473 sq. ft.*	2,926 sq. ft.
Grate Area	78 sq. ft.	53.4 sq. ft.	59.2 sq. ft.	78 sq. ft.	43.5 sq. ft.	35 sq. ft.
Wheelbase, Driving	30′ 0″	28′ 11″	16′ 0″	30′ 0″	16′ 6″	14′ 8″
" " Rigid	10′ 0″	9′ 10″	16′ 0″	10′ 0″	16′ 6″	14′ 8″
" " Total	44′ 10″	43′ 7″	24′ 3″	44′ 10″	34′ 9″	23′ 3″
Estimated Tractive Power B. L. W. formula	71,700	61,000	41,500	71,700	46,620	44,400
Tender Tank Capacity	8,000 gals.	8,000 gals.	6,000 gals.	8,000 gals.	8,000 gals.	5,500 gals.
Weight on Drivers	316,000 lbs.	263,000 lbs.	180,000 lbs.	313,500 lbs.	201,500 lbs.	166,000 lbs.
Total Weight	355,000 lbs.	302,000 lbs.	195,000 lbs.	351,000 lbs.	258,000 lbs.	186,000 lbs.
Wt. of Engine and Tender	252 tons	231 tons	157 tons	250 tons	209 tons.	149 tons.

* Including Combustion Chamber

their performance on the roads in this country where they have been most extensively used, but have not discovered any reasons why they are not well adapted to the conditions of American service.

Where simpler types of locomotives are adequate, the use of Mallet articulated locomotives is unnecessary; but where conditions limit the size and capacity of common type locomotives, we have found that increased power can be obtained through their use without changing the limiting conditions.

They have proved themselves practical, powerful, economical, flexible, and easy on the roadway when properly designed, and indications point to an increase in their numbers.

As an interesting comparison let me call your attention to the first shipment made by the Baldwin Locomotive Works over seventy-five years ago, when "Old Ironsides" was put in service, and a recent shipment of Great Northern Railway Mallet type locomotives, any one of which with their tenders would outweigh over fifty engines like "Old Ironsides."

It has given me pleasure, gentlemen, to discuss this important development of locomotive design, and in closing to direct your attention to the fact that, supplementing Mr. J. J. Hill's aggressive policy, considerable credit for problems solved and work done is due a firm of locomotive builders in this city, most of the members of which are also members of the Club.

DISCUSSION.

S. M. Vauclain.—When locomotive builders started work they used as few wheels as possible. The first engines had one pair of drivers to make the engines move and one pair of carrying wheels to keep them on the track. The boilers were built as small as possible to do the work and were placed between the wheels, and it is evident that only about one-half of the weight was available for adhesion.

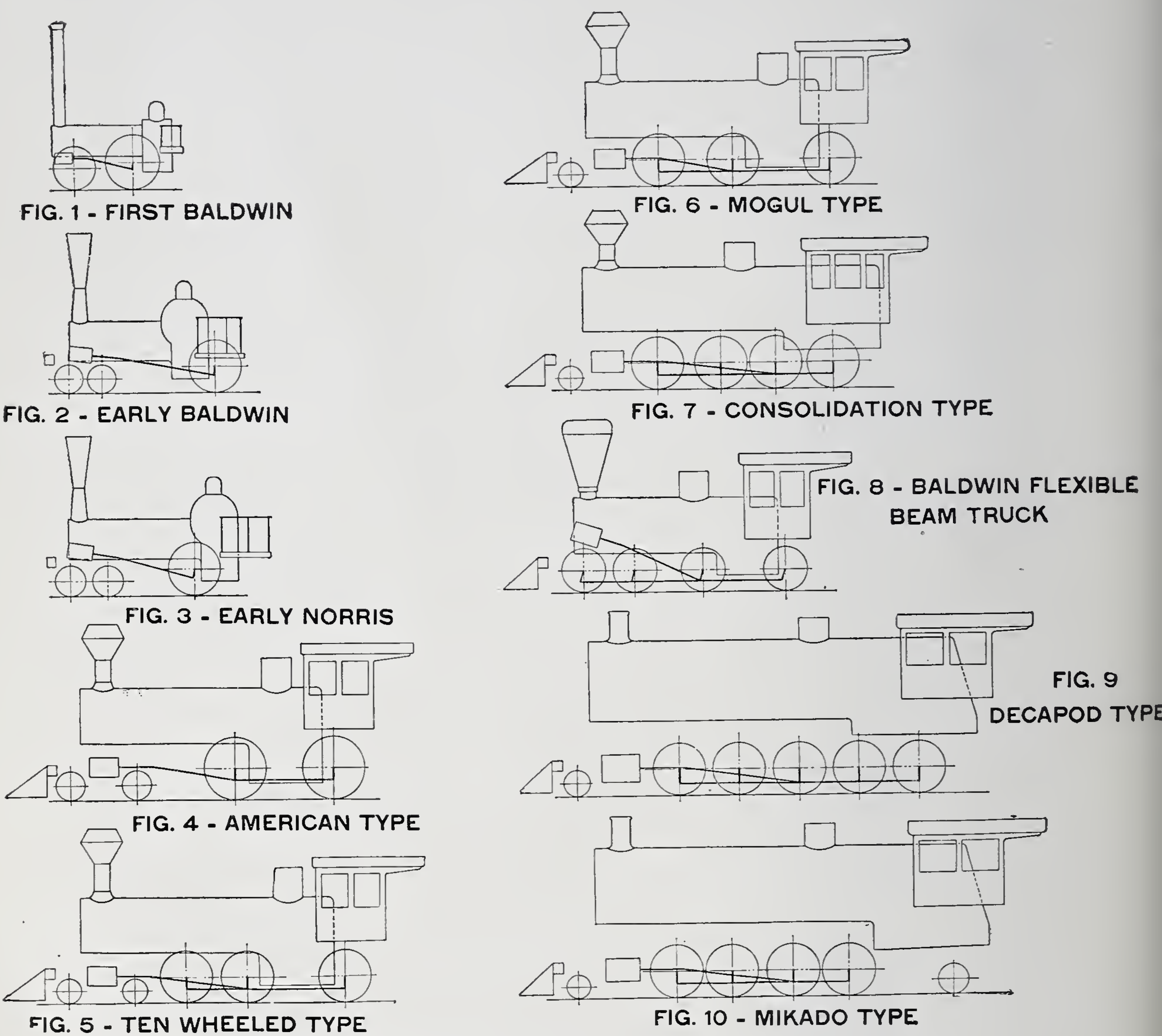
With the exception of Old Ironsides, Mr. Baldwin started by placing the drivers at the back and locating the firebox ahead of the driving axle (Fig. 2). Mr. Norris, in order to go one better, placed the firebox so that it would overhang back of the driving axle, which proved of decided advantage in four-wheeled locomotives by increasing the proportion of weight on the drivers, and so by obtaining increased adhesion he was able to haul more cars without increasing the total weight of the engine (Fig. 3).

The next important step was the introduction of a four-wheeled truck which enabled the engine to curve better and be easier on the track (Fig. 3).

To meet the wishes of the ever dissatisfied public an additional pair of driving-wheels was placed behind the firebox, and then the length of the firebox was increased as much as possible without lengthening the wheelbase unduly. This arrangement gave us the American type locomotive (Fig. 4).

Another locomotive gentleman, who improved upon previous construction, conceived the idea of increasing the number of driving-wheels to add to the proportion of weight needed for adhesion, and moved the truck forward sufficiently to slip in another pair of drivers back of the engine truck (Fig. 5).

Another one concluded it was ridiculous to carry so much weight on two pairs of truck wheels, so the idea was advanced to remove the back truck wheels and travel with one pair of truck wheels ahead of the cylinders, so that instead



Diagrams Illustrating Mr. Vauclain's Discussion.

of having about 70 per cent. of the weight on driving-wheels he would have 75 per cent. or more, and thereby rid the locomotives of useless wheels (Fig. 6).

The first Mogul locomotive was in this way developed from a Louisville and Nashville ten-wheeler. Then it was thought that an improvement could be made by moving the truck a little ahead and the drivers a little back, and use still more of the weight of the locomotive for adhesion, and another pair of drivers was placed back of the cylinders, making the Consolidation locomotive (Fig. 7).

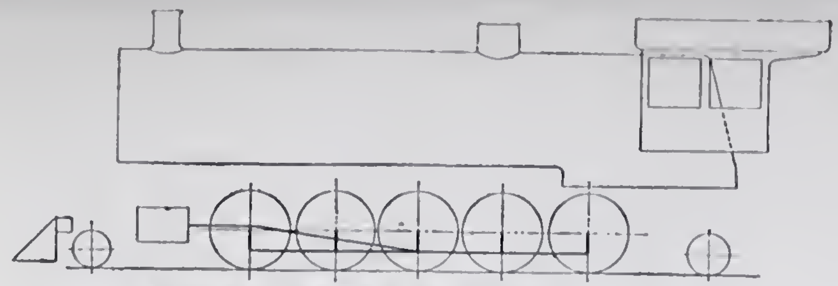


FIG. 11 - SANTA FE TYPE

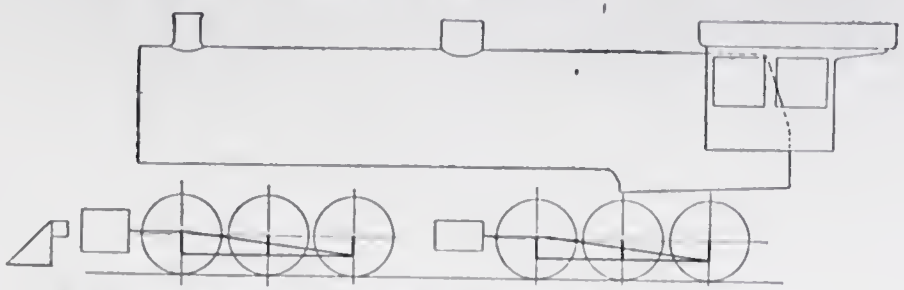


FIG. 12 - MALLET TYPE WITHOUT TRUCKS

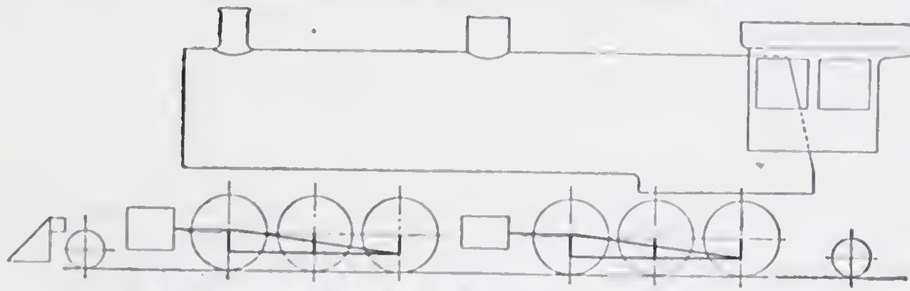


FIG. 13 - BALDWN MALLET TYPE

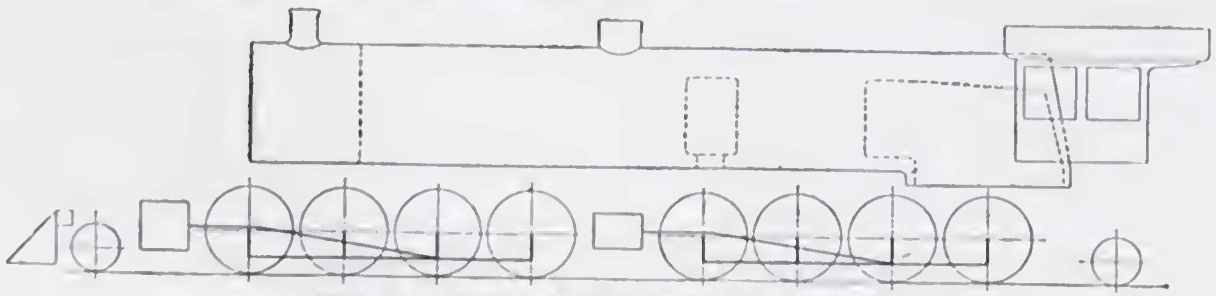


FIG. 14 - PROPOSED MALLET TYPE

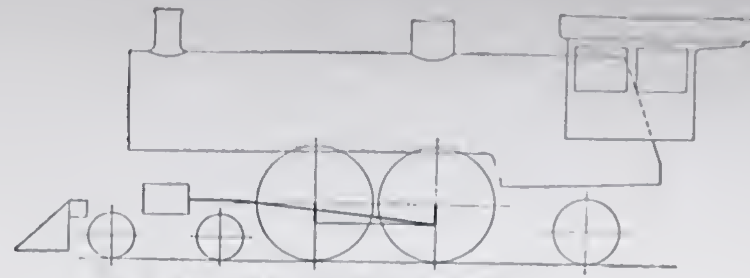


FIG. 15 - ATLANTIC TYPE

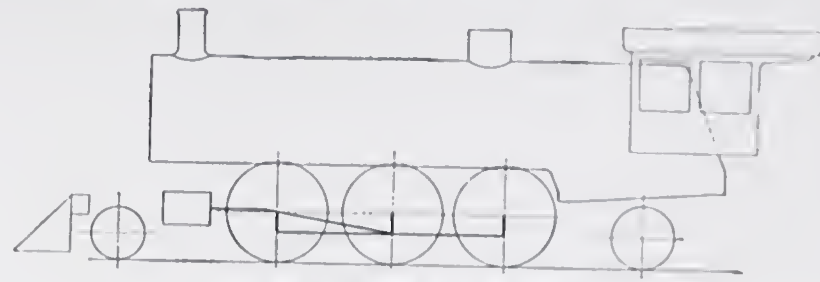


FIG. 16 - PRAIRIE TYPE

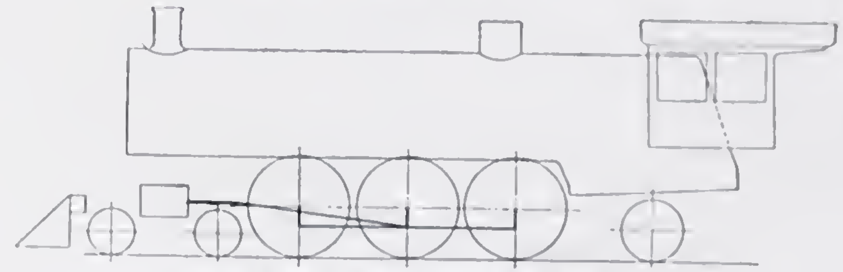


FIG. 17 - PACIFIC TYPE

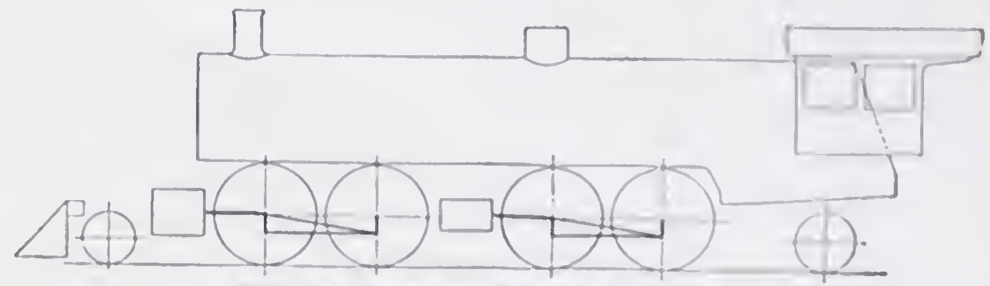


FIG. 18 - PROPOSED MALLET TYPE
FOR PASSENGER SERVICE

Diagrams Illustrating Mr. Vauclain's Discussion.

The next suggestion was, why not use four pairs of driving-wheels and do away with the truck wheels? That, however, was not successful in American service, and to overcome the difficulty Mr. Baldwin introduced his flexible beam truck, in which he placed some of the drivers, which permitted the locomotives to negotiate sharper curves than was possible where drivers were fixed in a rigid wheelbase. That arrangement necessitated placing the cylinders on an angle as star-gazers and raising the smoke-box (Fig. 8).

To revert to the Consolidation freight locomotive—several people have been credited with being the father of that locomotive, but it seems to be established that the first one was built by Mr. J. B. Laird at Altoona. An idea was then developed to design freight locomotives with five pairs of drivers coupled together (Fig. 9), and several attempts in that direction were made, notably on the Northern Pacific Railway and later on the Sante Fe system. That was after we had built heavy Mikado type locomotives (Fig. 10) and heavy Consolidations. Then Mr. Kendrick, who is one of the most progressive locomotive buyers and operates one of the most economical railroads in the United States, after obtaining two of these decapods, found that they could be run forward around the curves without trouble, but that if he undertook to back the locomotives the rear driving-wheels instead of being turned by the rail would often turn the rail. Then we built this locomotive similar to the Mikado type and made it a decapod with a controlling truck (Fig. 11). This was shown by Mr. Greenough, and is the type of engine used in Sante Fe Railway freight service today. The limit of weight on any one of these driving-wheels is 25,000 pounds. On balanced locomotives a weight of 30,000 pounds has been used on the same road, but with the Sante Fe type we cannot use 30,000 pounds on each driver on that road.

In the meantime the Baltimore and Ohio road had purchased from the American Locomotive Company an articulated engine having twelve driving-wheels and no trucks (Fig. 12). Mr. Hill was persuaded to equip one division of his road with five locomotives of the Mallet type with trucks front and back to relieve them on curves (Fig 13), and they have given splendid satisfaction. It was feared that they could not be gotten into the round-house, but when they were placed in operation in 1906 and 1907 there was so much snow that they were not allowed to go anywhere near the round-house, as they were kept busy going up the grades forward and then down again backward. After six months' usage it was found that the driving flanges had not worn, thus vindicating the use of leading and trailing trucks. This led Mr. Hill to use them also for heavy work on 1 per cent. grades; his idea being that they could bring a maximum load over the 1 per cent. grades that two smaller engines could not handle without cutting or drilling.

You will notice that these engines are practically two Moguls with one of them turned backward, but with cylinders of different diameters arranged to work steam at different pressure, so that instead of exhausting the steam from the high-pressure cylinders directly into the atmosphere, it is made to work expansively in the cylinders of the low-pressure engine.

The Erie Railroad went a step further and used four pairs of driving-wheels in a set, thus supporting the entire engine on eight pairs of driving-wheels, a type of engine that will probably not survive. This locomotive is capable of exerting a tractive power approximating 100,000 pounds, hence when pushing a

train it exerts that pressure, less the amount necessary to move itself and tender, against the coupling of the car in front of it. This pressure is sufficient to make the resistance to any tendency of the couplers to slide vertically upon one another equal to, say, 20,000 pounds. Most railroad tracks in this country are not as level as this floor, and consequently any vertical movement in the engine or car will cause a strain either upon the car or locomotive in proportion to the pressure acting on the couplers, and will have the effect of materially changing the weight on the forward pair of driving-wheels, besides proving severe on the couplers, which are not securely supported. This trouble is largely obviated by the introduction of a front truck which reduces the overhang and steadies the engine.

Mr. Kendrick, who usually wants something better, is now considering the construction of Mallet type engines with four pairs of drivers in each section and trailing wheels front and back, thus practically combining two Consolidations in one. He wants the drivers 63 inches in diameter, so that they can be used in passenger service over the mountains. Fig. 14 gives an idea of the type of locomotives we are contemplating. In an engine of this kind we have to introduce an intermediate combustion chamber, otherwise the tubes would be longer than the moral law allows, and that would not do. This combustion chamber would be placed closer to the firebox than to the front tube sheet, so that the rear tubes could be removed through the firebox. The combustion chamber will have a water space entirely around it except at the manhole opening in the bottom. This locomotive, in working order, should weigh about 480,000 pounds, with 220,000 pounds on each set of drivers, and the remainder of the weight distributed on front and back trucks to keep them steady.

Passenger service was mainly handled for a number of years by the American type locomotive (Fig. 4), which developed to the Atlantic type (Fig. 15), in order to provide a larger firebox, which in turn has given way to the Prairie type (Fig. 16) and the Pacific type (Fig. 17) for heavy service. The New York Central and Hudson River Railroad has made the limit for Pacific type engines 171,000 pounds on driving-wheels, while the Sante Fe system have Prairie type engines with 176,000 pounds on drivers, but even this will not do, and we must make changes to accommodate our friends who are interested in heavy passenger work. We are now preparing designs for an engine with 73-inch driving wheels (Fig. 18). This locomotive will have from 220,000 pounds to 240,000 pounds on driving-wheels, or approximately 30,000 pounds on each driver, and it is expected that the engine will be capable, notwithstanding this great weight, of attaining a speed of 70 miles an hour.

You will see from what I have said there is practically no limit to the number of wheels you can put under a locomotive. We used to think that locomotive building required more or less science, but we are beginning to feel, like the old wagon-builders, that locomotive building is simply a question of putting all the wheels you can under boilers.

James Christie.—In connection with this interesting type of locomotive, and its designer, Anatole Mallet, it is worthy of notice that M. Mallet was one of the early originators of the compound locomotive. He built in 1876 several two-cylinder compound engines, which proved so successful that they were followed by many others, and thus gave the first impetus to the adoption of compound locomotives in Europe.

These engines had special valve gear to facilitate starting, permitting the engines at will to be operated either simple or compound—a device that has been accredited to others of later date.

He introduced the articulated compound about 1887, and this engine has proved so successful on the Alpine railways, and others where steep grades are combined with sharp curves, that approximately one thousand engines of this type have been introduced. Its utility was well established in Europe before its introduction into this country. Those interested in the subject can derive much information from a paper contributed by M. Mallet to the American Society of Mechanical Engineers and published in their transactions of 1893.

PAPER NO. 1053.

A NEW DEVELOPMENT IN CROSS-SECTION PAPER.

HENRY HESS.
(Active Member.)

Read April 18, 1908.

1. AN improvement in cross-section paper that is believed to be new and original, and that has proved valuable in the writer's work, is here presented to the profession.

This paper is confined to one phase of the subject, that relating to the graphic derivation of an expression, law or formula defining the quantitative relationship of plotted observations.

2. Of cross-section papers, two types are in more or less general use; that shown as Fig. 1 has equal spacing and will hereafter be referred to as "Plain"; the other, Fig. 2, has logarithmic spacing, to be hereafter referred to as "Logarithmic."

3. The improvement is in both forms and is shown in both figures by the addition of certain scales at the top and right sides. This scale starts with 1 at the upper right corner and then runs down by even dimensions as 0.9, 0.8, 0.7, etc., to 0 at the left top corner and right bottom corner. These scales make possible, without resort to calculation, the ready and graphic determination of certain constants in a formula that is sought.

4. The terms used herein are, whenever possible, such as the ordinary shop man would employ, rather than the technical expressions of the mathematician; the latter will have no trouble in following these even though he may not approve them, considering his technical ones shorter and more precise, a contention that may be granted, but that will not help the man with the other training.

5. Equations expressing the relationship of two quantities are, as far as observations in the domain of an average engineer's experience are concerned, chiefly of the form

$$A = \pm y B^{\pm x} \pm z$$

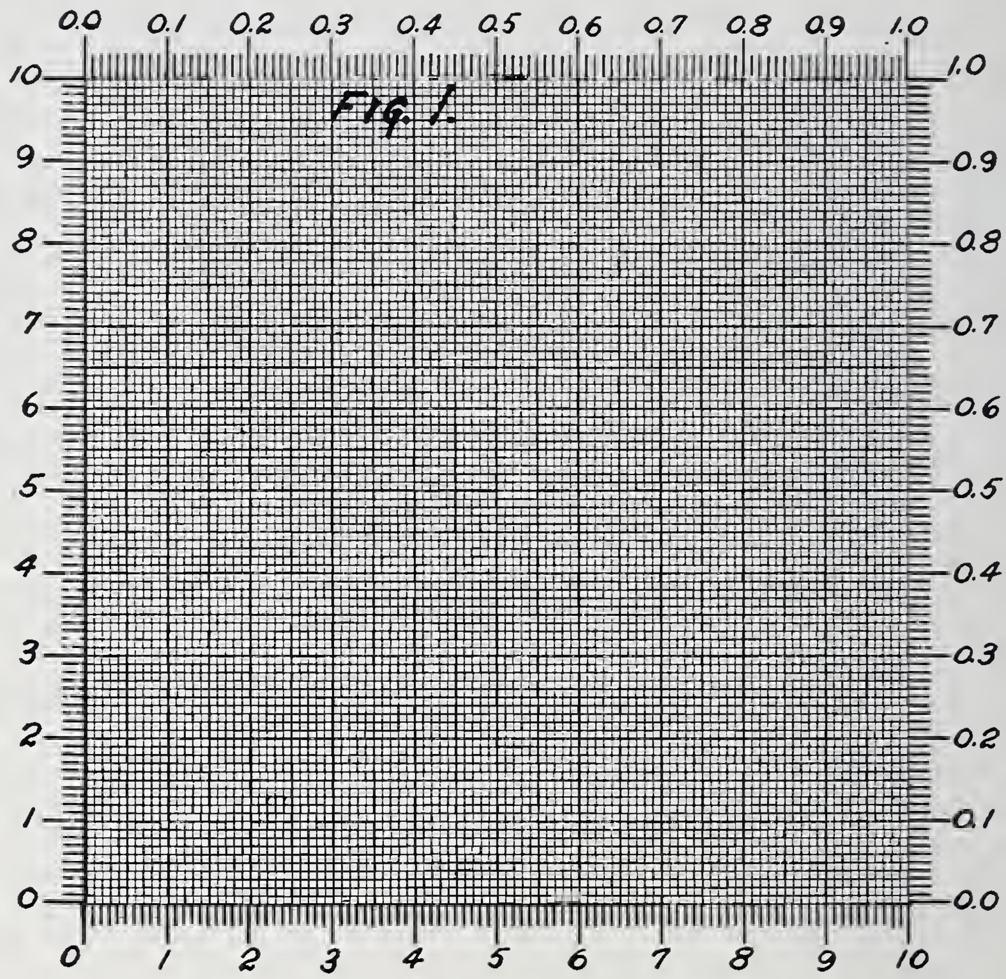
The new top and right scales facilitate the determination of the values of y and x.

6. As long as the expression involves the first power, or x = 1, the equation takes the form

$$A = \pm y B \pm z$$

A line expressing it will be a straight line when plotted on plain paper. Plain paper may therefore be logically employed in such case.

7. When, however, x has some value other than 1, whether larger



or smaller, then the line expressing the relationship will be curved when the data are plotted on plain paper; if the data are plotted on logarithmic paper, the line will often be straight. If it is suspected that powers are involved, the data should therefore be plotted on logarithmic paper; if plotting on plain paper gives a curved line, replotting on logarithmic paper will be advisable. In the following presentation, mathematical reasoning will be avoided and the various lines that show the character of the relationship of the observations hereafter termed "characteristics" will be explained by taking up each in turn.

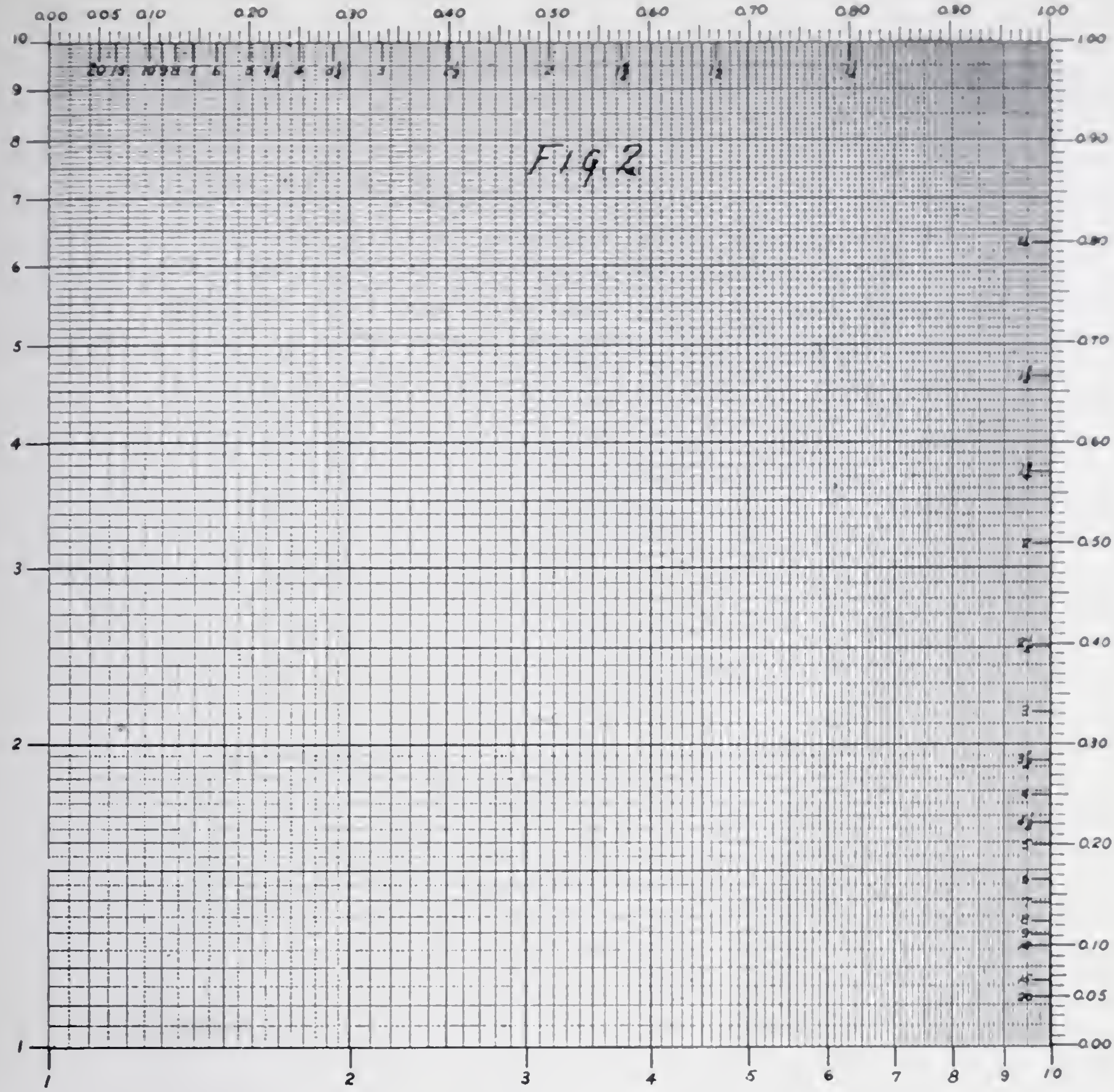


FIG. 2

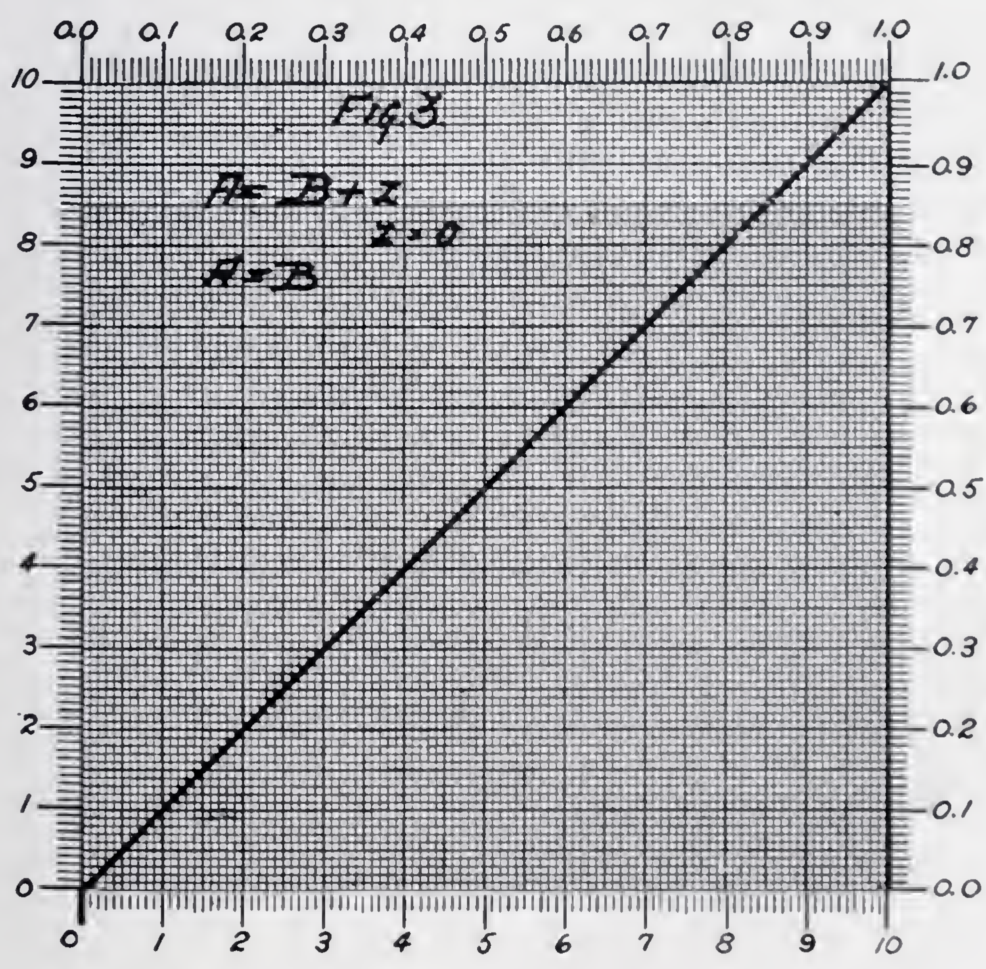


Fig. 3
A = B + Z
Z = 0
A = B

Plain Paper Straight Line Characteristics.

8. In Fig. 3 the characteristic starts at the left bottom zero or origin and proceeds diagonally to the top right hand corner and scale value 1. We know it to be expressed by the general equation

$$A = \pm y B \pm z$$

Whenever the characteristic starts from origin 0, that means that $z = 0$. Whenever the characteristic starts from origin 0 and meets or intercepts the top scale at 1, that means that $y = 1$. Wherever the characteristic trends from left to right upward we know that y is +. Therefore for this characteristic we have

$$A = + 1 B \pm 0 \text{ or } A = B$$

9. In Fig. 4 the characteristic has its origin on the left scale; the value of the intercept gives z; in this case 4. To get the value of y, a parallel line to the characteristic is dotted through 0 as the origin. This parallel may be termed the secondary characteristic or, shortly, the "secondary." The intercept of this secondary with the top scale gives the value of y as in Fig. 1. Therefore we have for the characteristic

$$A = B + 4$$

10. In Fig. 5 the characteristic is similar to that of Fig. 4, differing only in not intercepting the left scale; we therefore prolong it to intersection with the prolongation of the left scale.

11. Whenever the characteristic prolonged intercepts the prolongation of the left scale below zero, the value of z will be given by the intercept, but z will be minus. In this case therefore

$$z = - 4$$

Dotting in the secondary as described for Fig. 4 shows $y = 1$. We therefore have

$$A = B - 4$$

12. In Fig. 6 the characteristic trends from left to right, but downward instead of upward. Whenever the characteristic runs downward from left to right, y is minus. As before, z is given by the intercept with the left scale, in this case at 10, so that $z = 10$. To determine y, the secondary must be drawn in. Two methods are available;

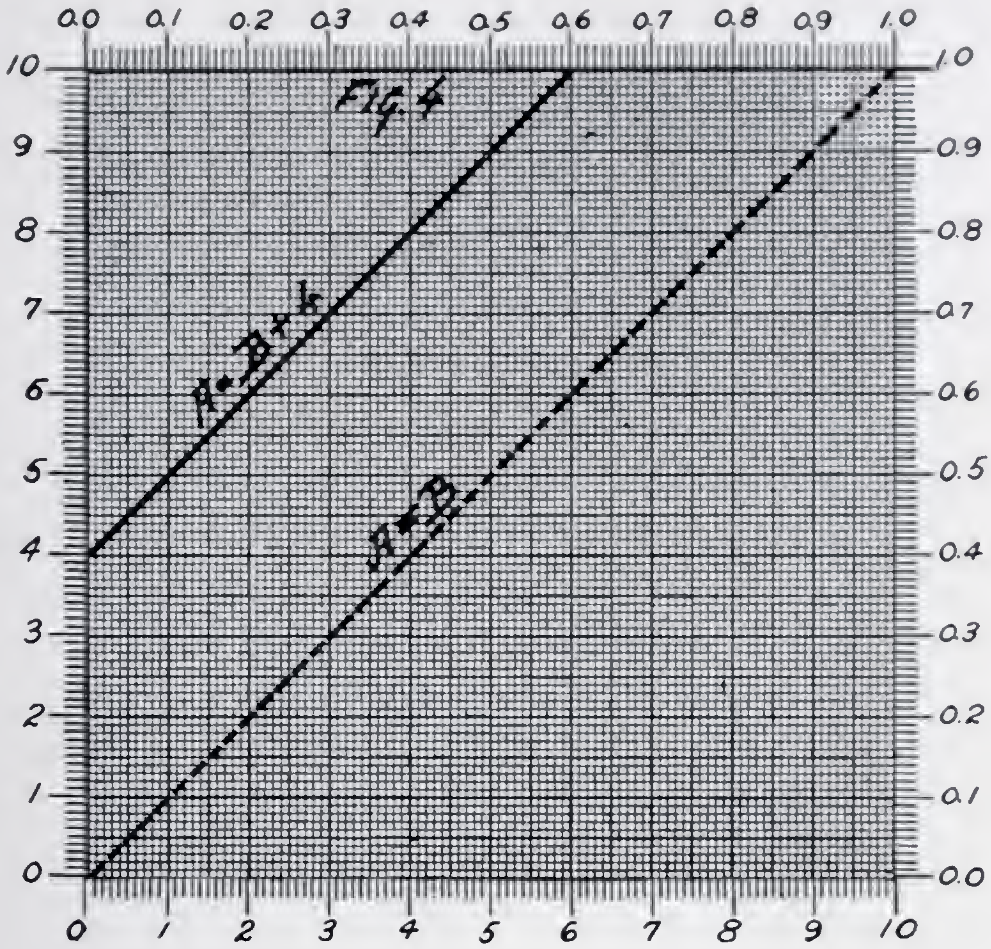


Fig. 4
A=B+k
A=B
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

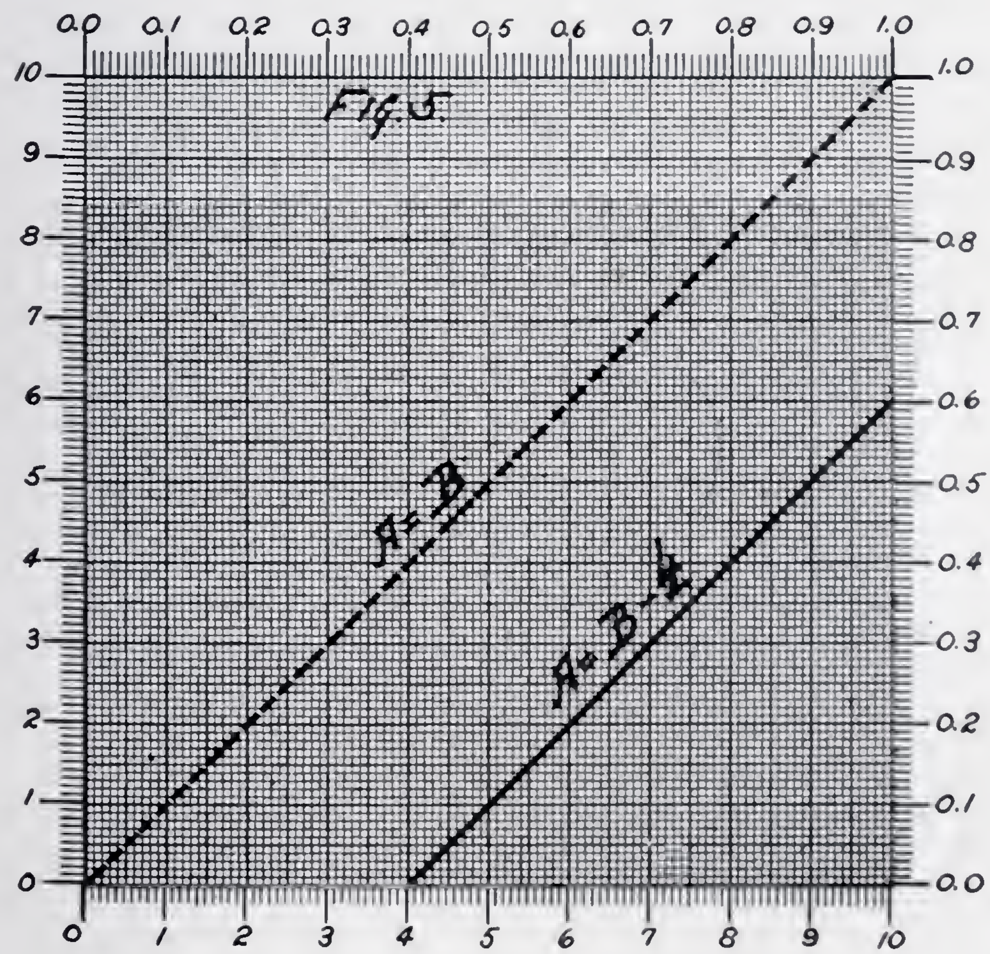


Fig. 5.
A=B
A=B-k
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

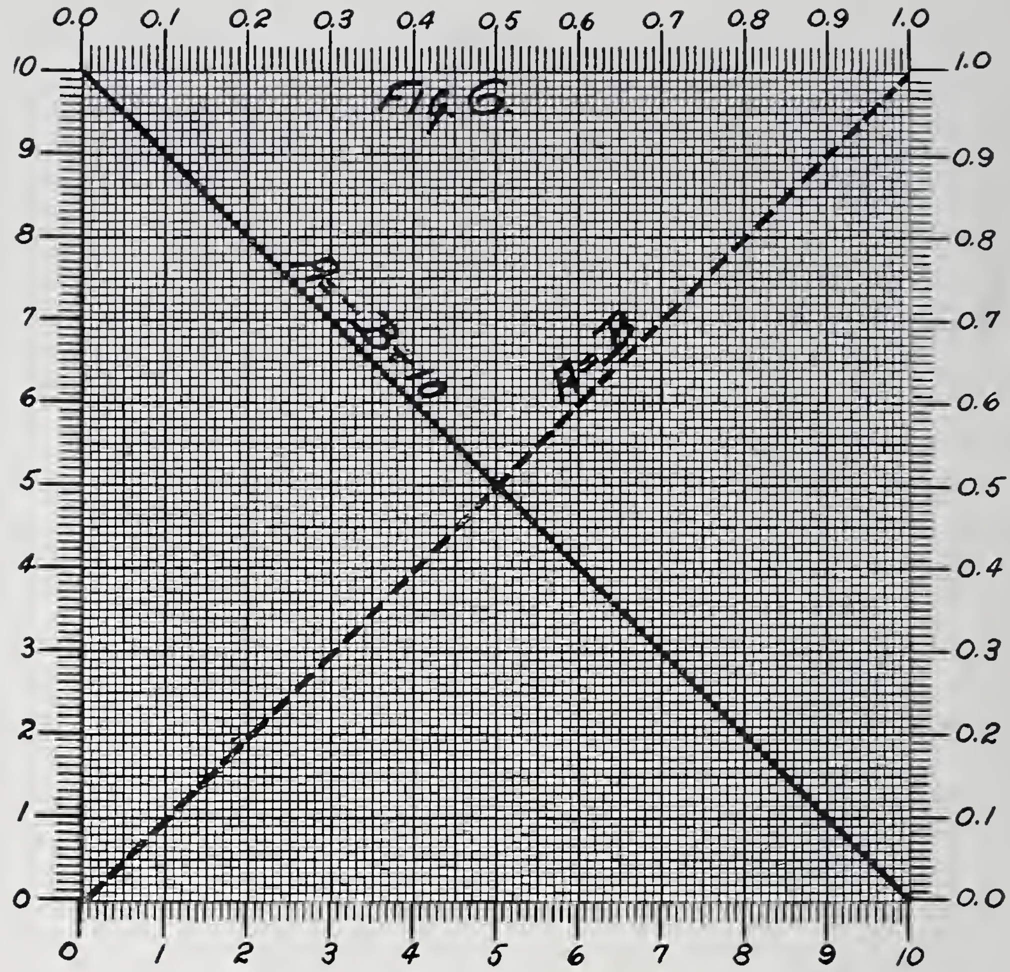


Fig. 6.
A-B=10
A=B
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
1
2
3
4
5
6
7
8
9
10

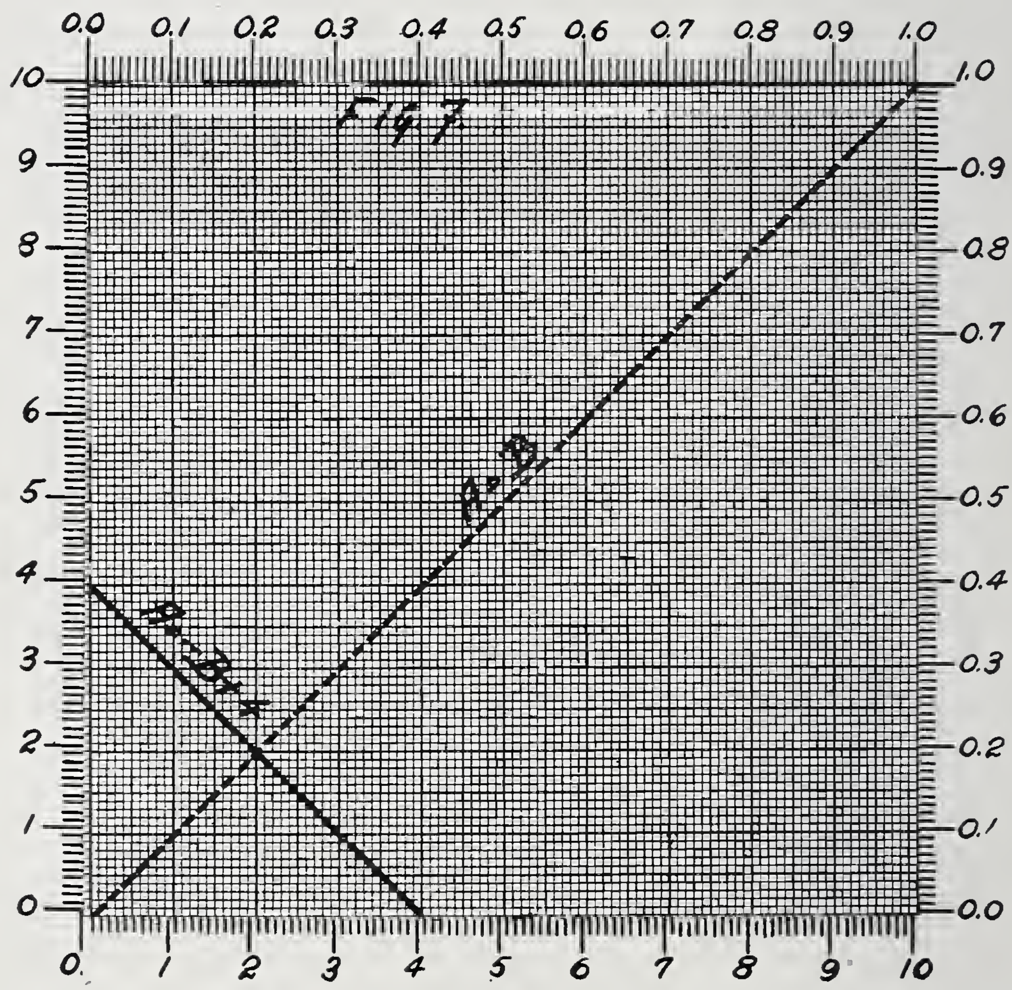


Fig 7
A-B+4
A=B
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
1
2
3
4
5
6
7
8
9
10

the one that I prefer starts y at the left bottom origin 0 at the same angle upward to the right as the primary characteristic trends downward. The intercept with the top and right scale gives as before, y = 1. From this we get

$$A = - B + 10$$

13. In Fig. 7 the left to right downward trend again indicates that y is minus and the intercept with left scale gives Z = 4. The secondary again shows y = 1, so that

$$A = - B + 4$$

14. In Fig. 8 the characteristic prolonged intercepts the left scale prolonged at 14, giving z = 14 and the secondary shows y = 1, while the left to right downward trend of the characteristic gives y as minus, so that

$$A = - B + 14$$

15. Fig. 9 differs from Fig. 3 only in the intercept of the characteristic with the top scale being at 0.4 instead of at 1. This intercept gives the value of y. The top scale might be made to read y directly, but its divisions would then not be even and interpolations for fractional values consequently difficult. Instead, the evenly divided scale is used; with that y is the reciprocal of the scale value. Whenever the characteristic or its secondary intercepts the top scale, the value of y is greater than one. In this case the intercept is at 0.4, so that $y = \frac{1}{0.4} = 2.5$.

The other quantities are determined as in connection with Fig. 3; therefore

$$A = 2.5\ B \pm 0 \qquad\qquad A = 2.5\ B$$

16. Fig. 10 gives y + and z = + 5 as before explained. To get y quantitatively dot in the secondary from 0 and find that it intercepts the top scale at 0.4 whose reciprocal, 2.5, is y. So that

$$A = 2.5\ B + 5$$

17. In Fig. 11 the prolongation of the characteristic with the prolongation of the left scale gives z = — 12.5. As before, we get

$$A = 2.5\ B - 12.5$$

18. Fig. 12 has the characteristic trending downward from left to right which means that y is minus. Proceeding as before gives

$$A = - 2.5\ B + 10$$

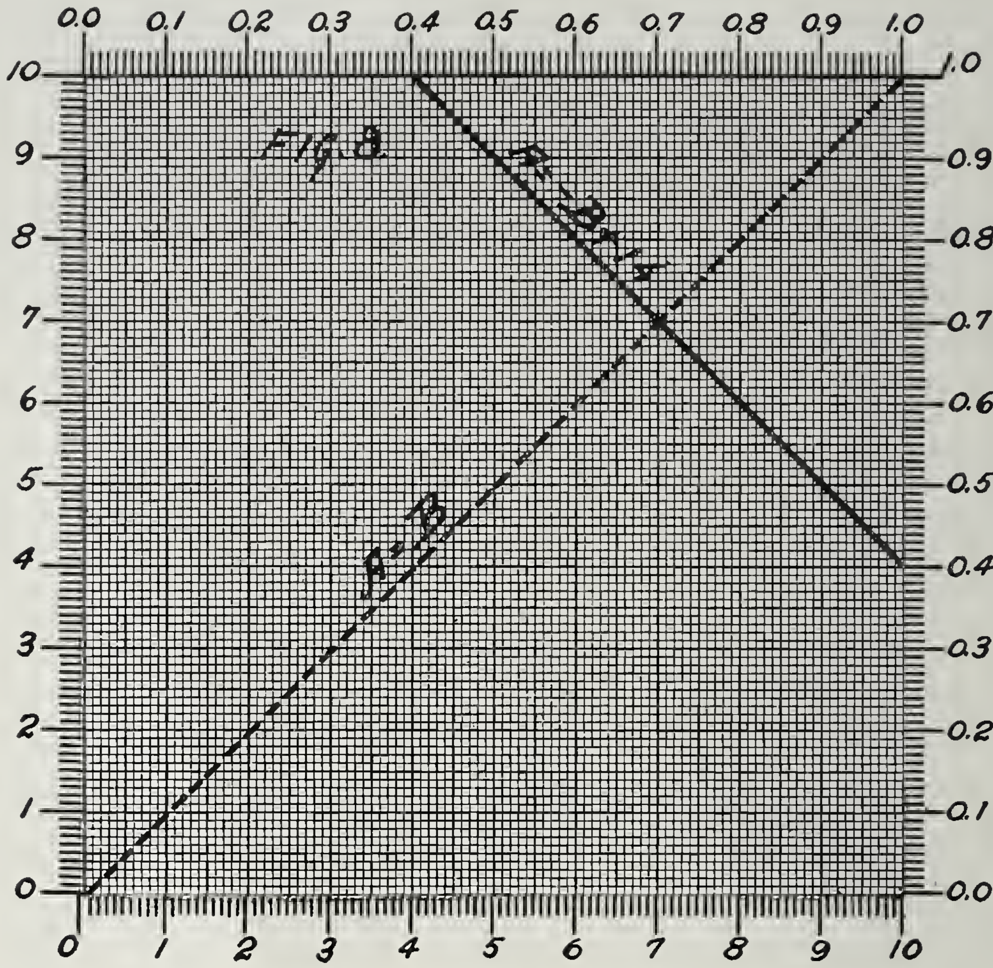


Fig. 8
A = -B + 14
A = B
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

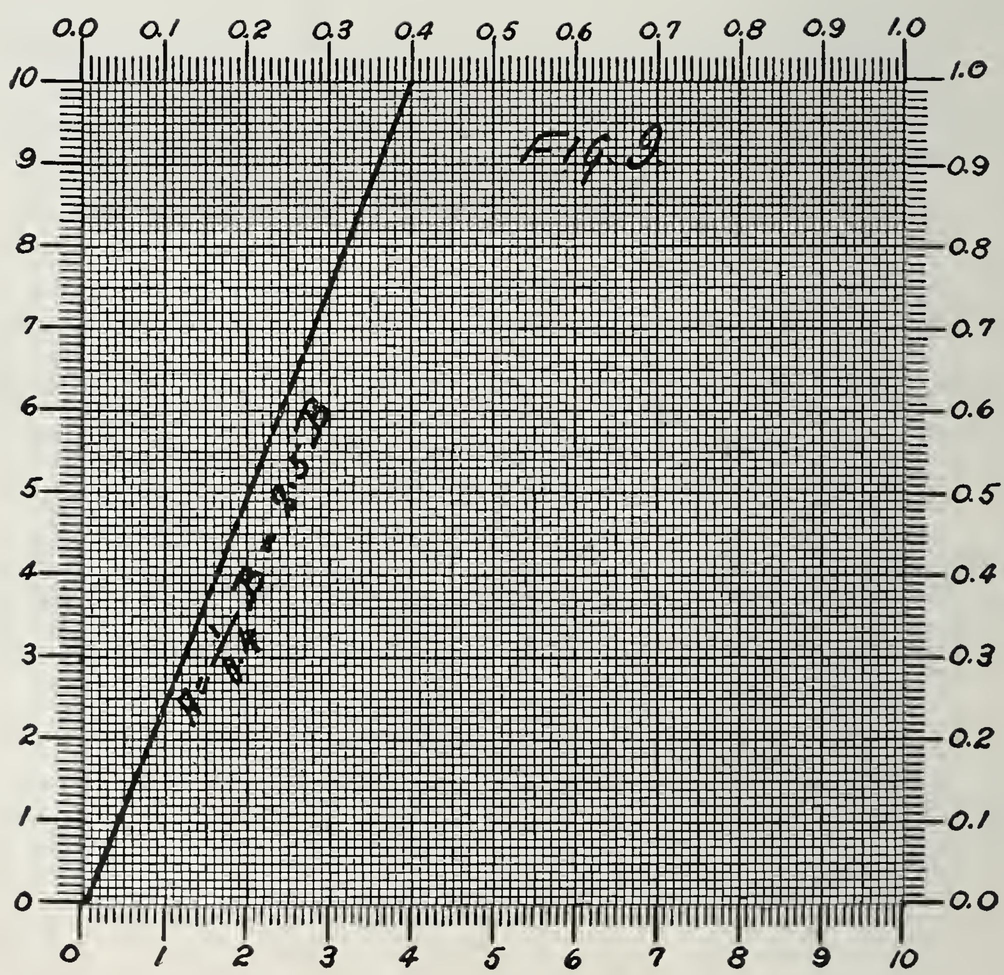


Fig. 9
A = 1/.4 B = 2.5 B
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

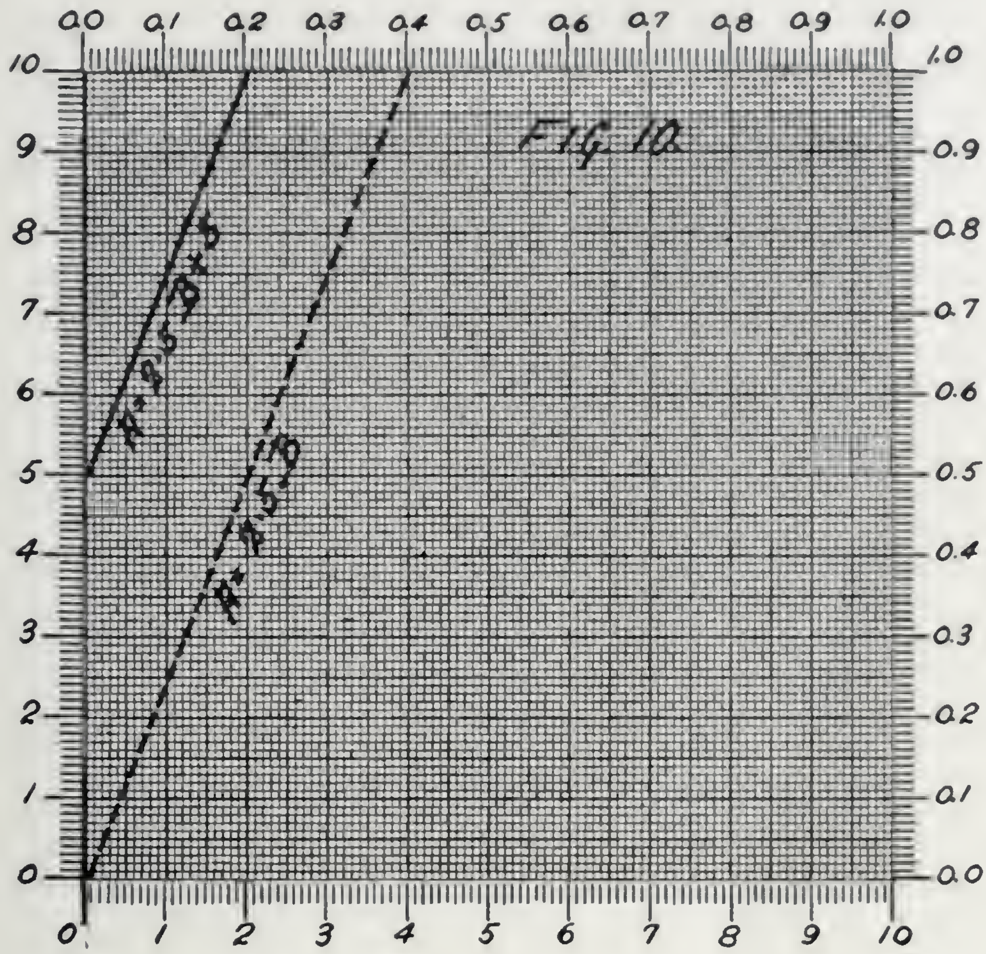


FIG. 10

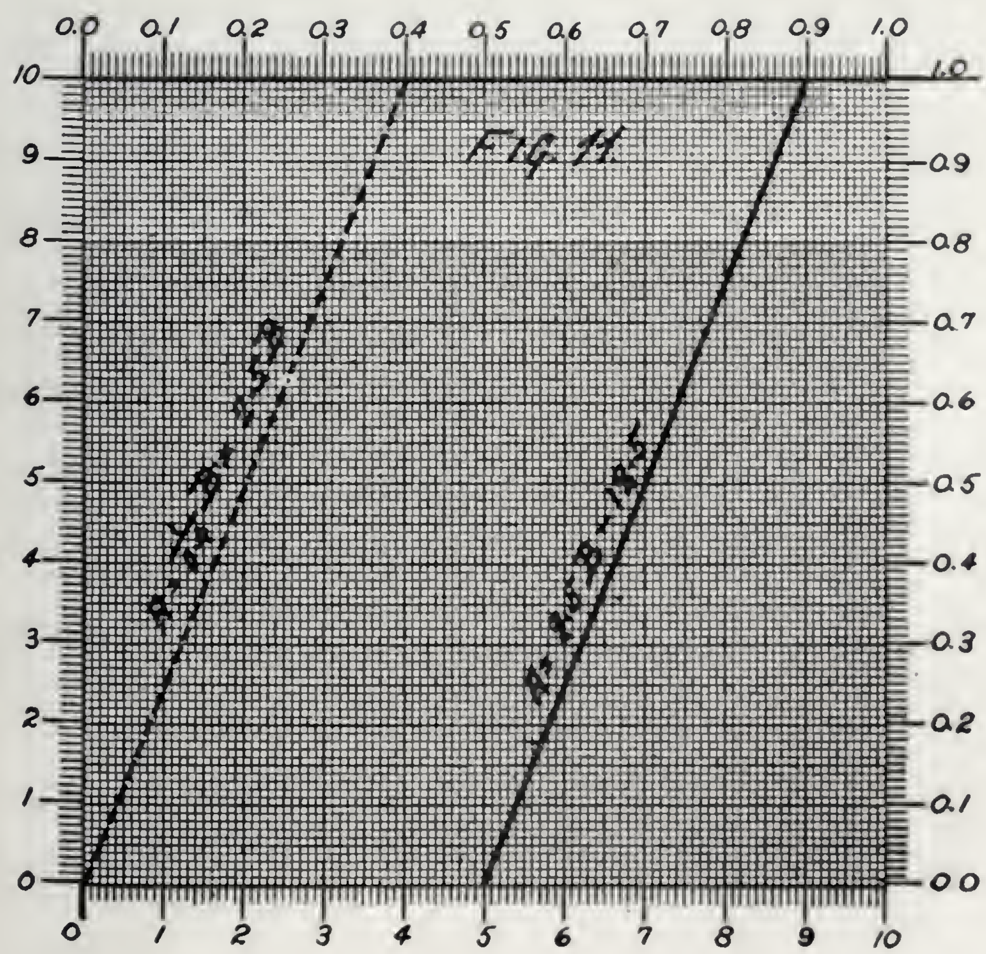


FIG. 11

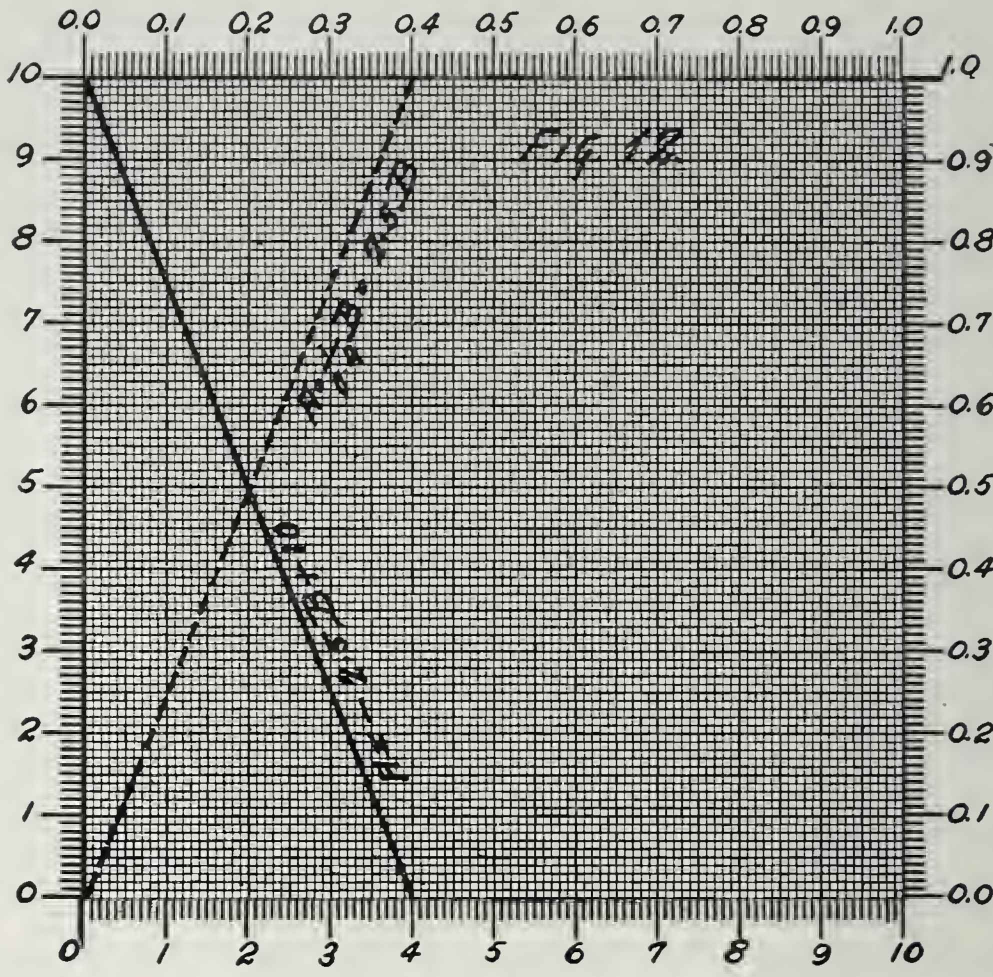


Fig. 12

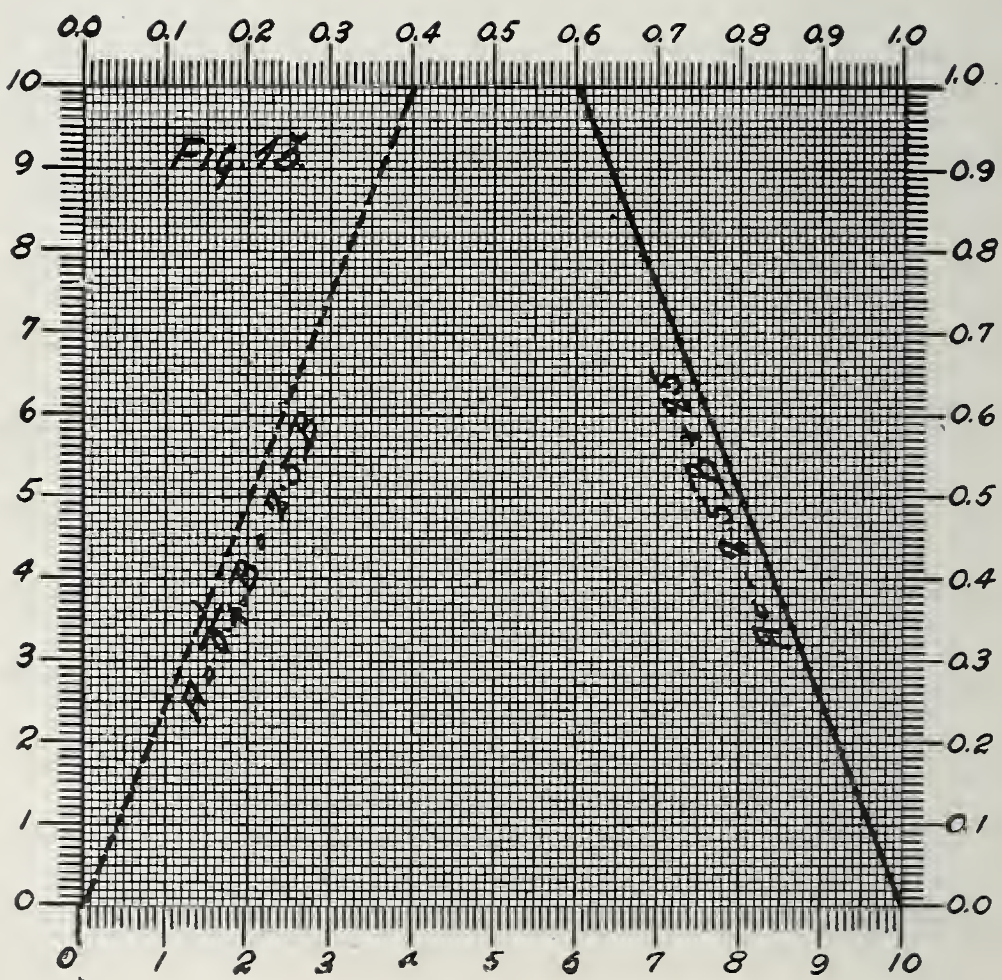


Fig. 13

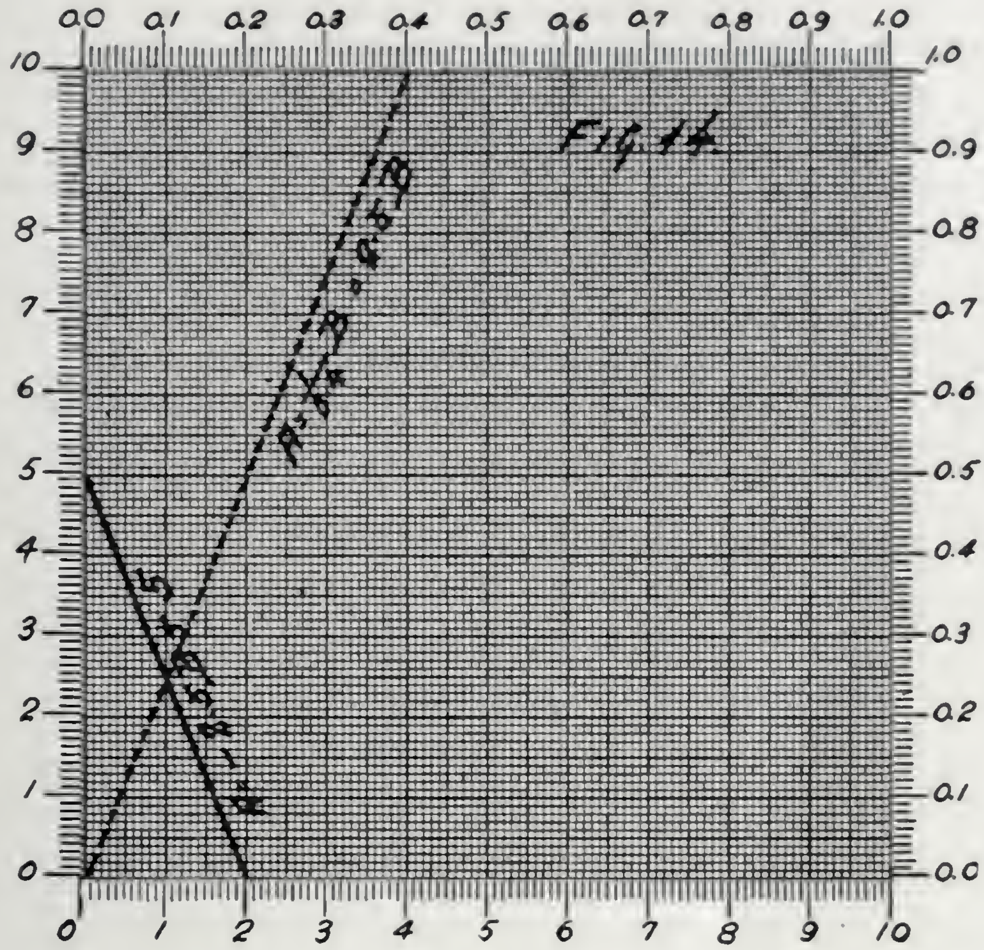


FIG. 14

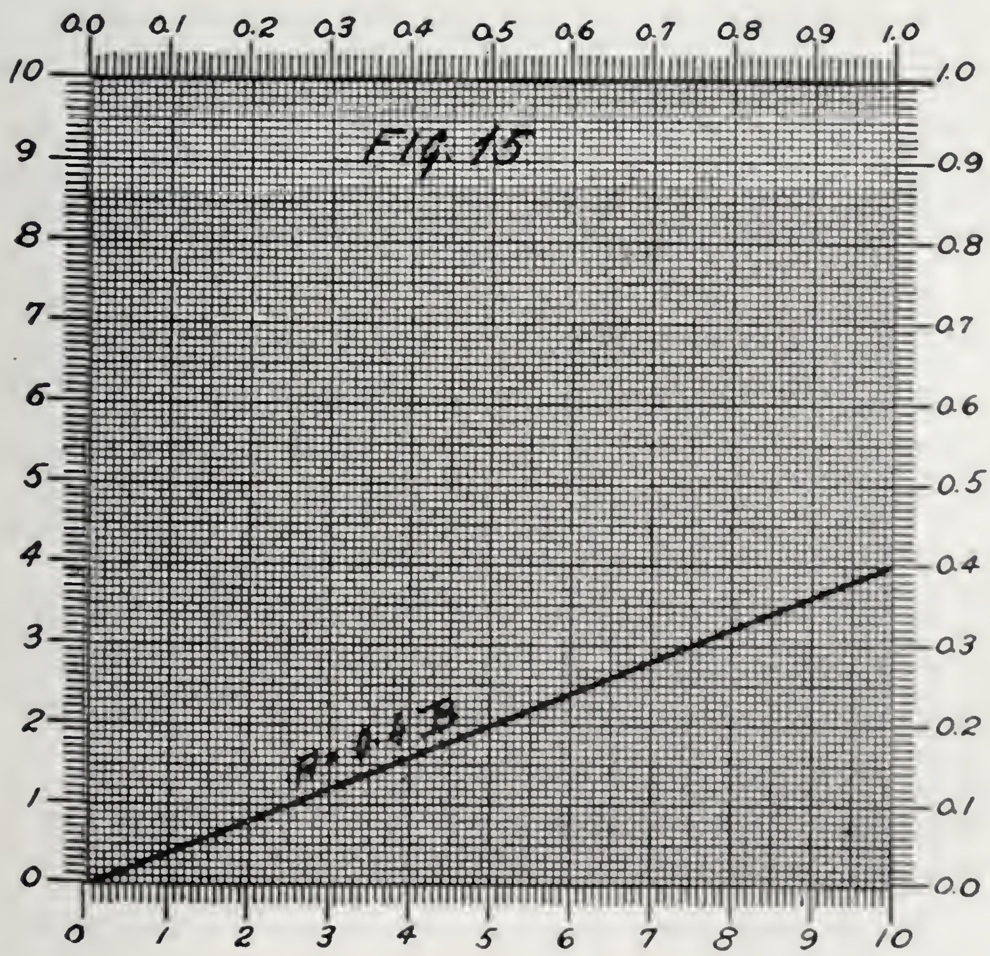


FIG. 15

Figs. 13 and 14 will be clear from the preceding.

Fig. 13	A = — 2.5 B + 25
Fig. 14	A = — 2.5 B + 5

19. In Fig. 15 to 20 the characteristics lie at a lesser inclination with reference to the horizontal; the characteristic or its secondary intercepts the right hand scale instead of the top scale. Whenever the secondary intercepts the right hand scale, the value of y is less than 1; that value is directly read at the intercept.

20. With this and the preceding explanations the equation for these Figures will be clear without further detailed explanation; they are:

Fig. 15	A = 0.4 B
Fig. 16	A = 0.4 B — 2
Fig. 17	A = 0.4 B + 2
Fig. 18	A = — 0.4 B + 10
Fig. 19	A = — 0.4 B + 12
Fig. 20	A = — 0.5 B + 2

21. By comparing Figs. 5, 11 and 16 it becomes clear why the value of z must not be taken at the intercept of the characteristic with the bottom scale, but at the intercept of the prolongation of the characteristic with the prolongation of the left scale. An apparent exception is found in Fig. 5, but that is apparent only and due to the fact that the inclination of a primary characteristic whose secondary intercepts the top scale at 1 intercepts the bottom and the left scale (prolonged) at the same values; for other inclinations these intercepts are at different values.

22. It is sometimes convenient to assign different values to the left and bottom scales, in other words, to make these of different lengths.

23. Fig. 21 shows how this affects conditions. The top and right scales are again the new scales of even parts, but the characteristic A = B now has an inclination from left to right that is more nearly vertical than 45°. Fundamental difference there is none. As it is more convenient to use paper that has the values of the top and right scales printed and as it would be impracticable to have such paper in all of the possible variants of the relative right and bottom scale values, it will be better to use a constant multiplier for one or other scale and so permit the use of the prepared paper.

24. In connection with Fig. 6 it was mentioned that the secondary might be dotted in two ways; the one preferred was used. The other way is to always draw the secondary parallel to the primary characteristic; when the latter trends from left to right downward the

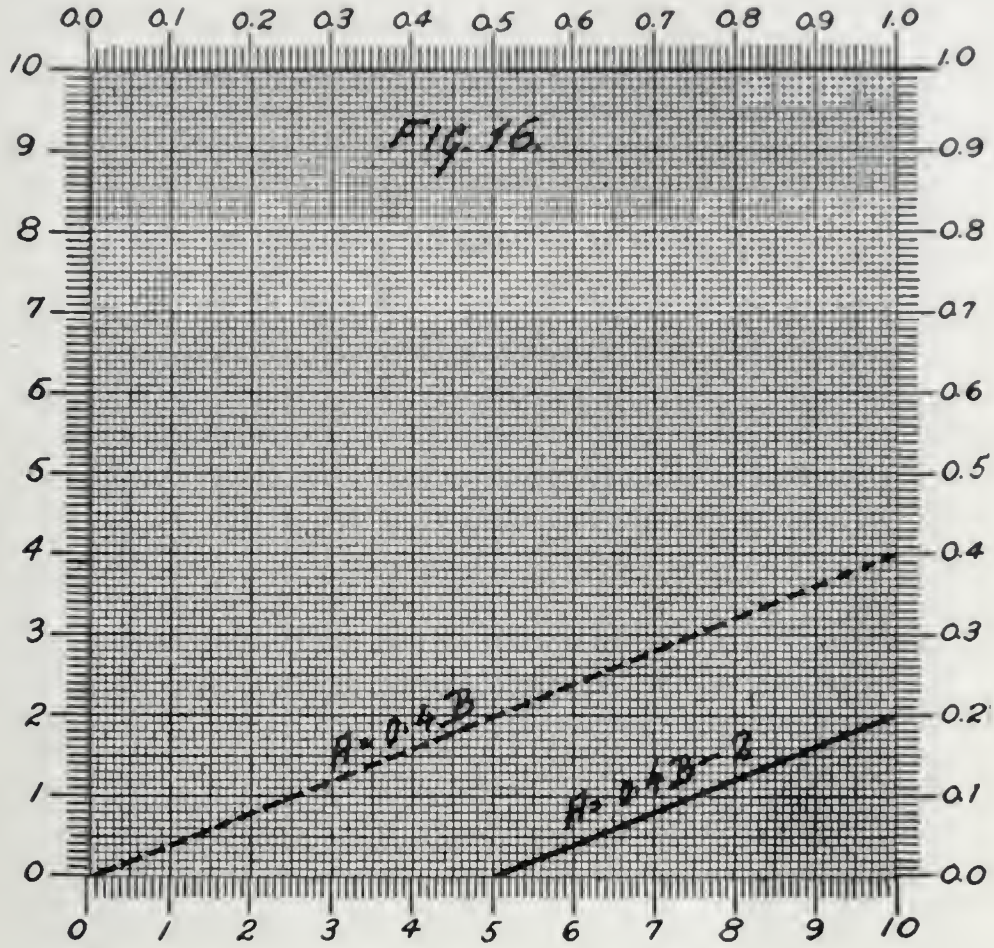


Fig. 16.
A = 0.4 B
A = 0.4 B − 2
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

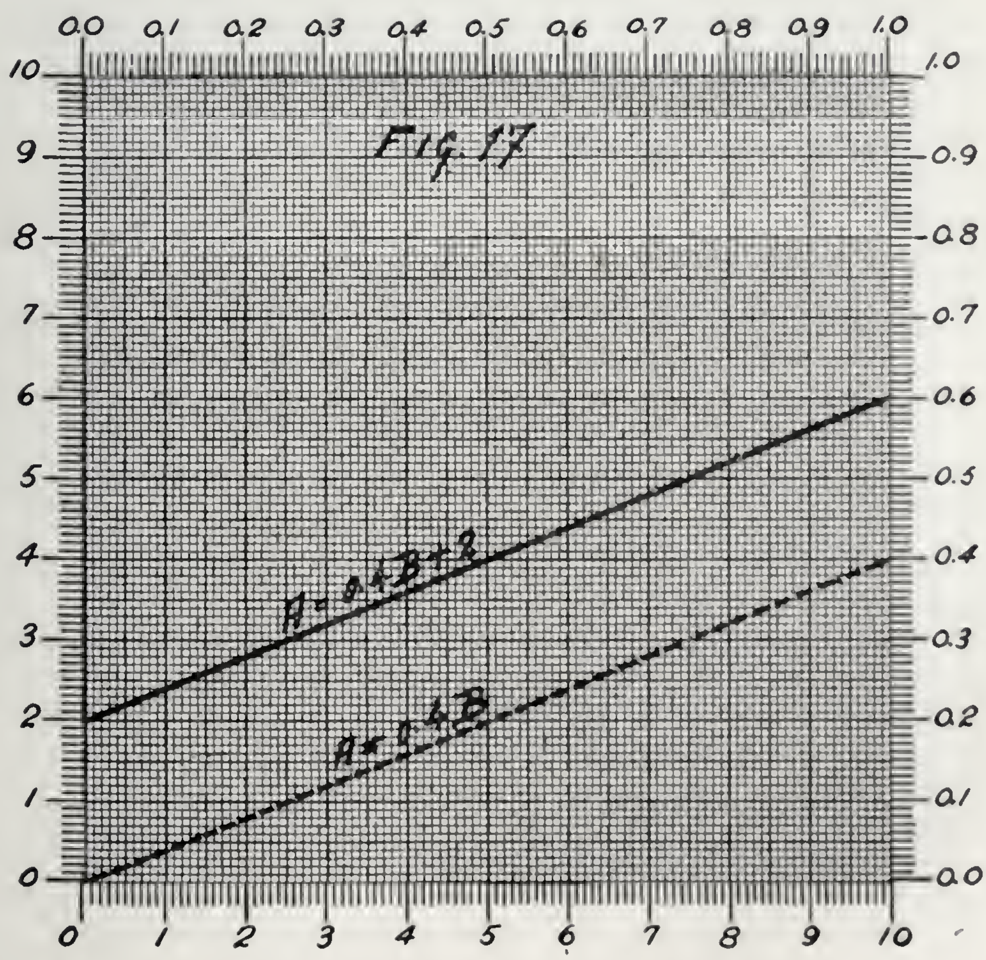


Fig. 17
A = 0.4 B + 2
A = 0.4 B
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10

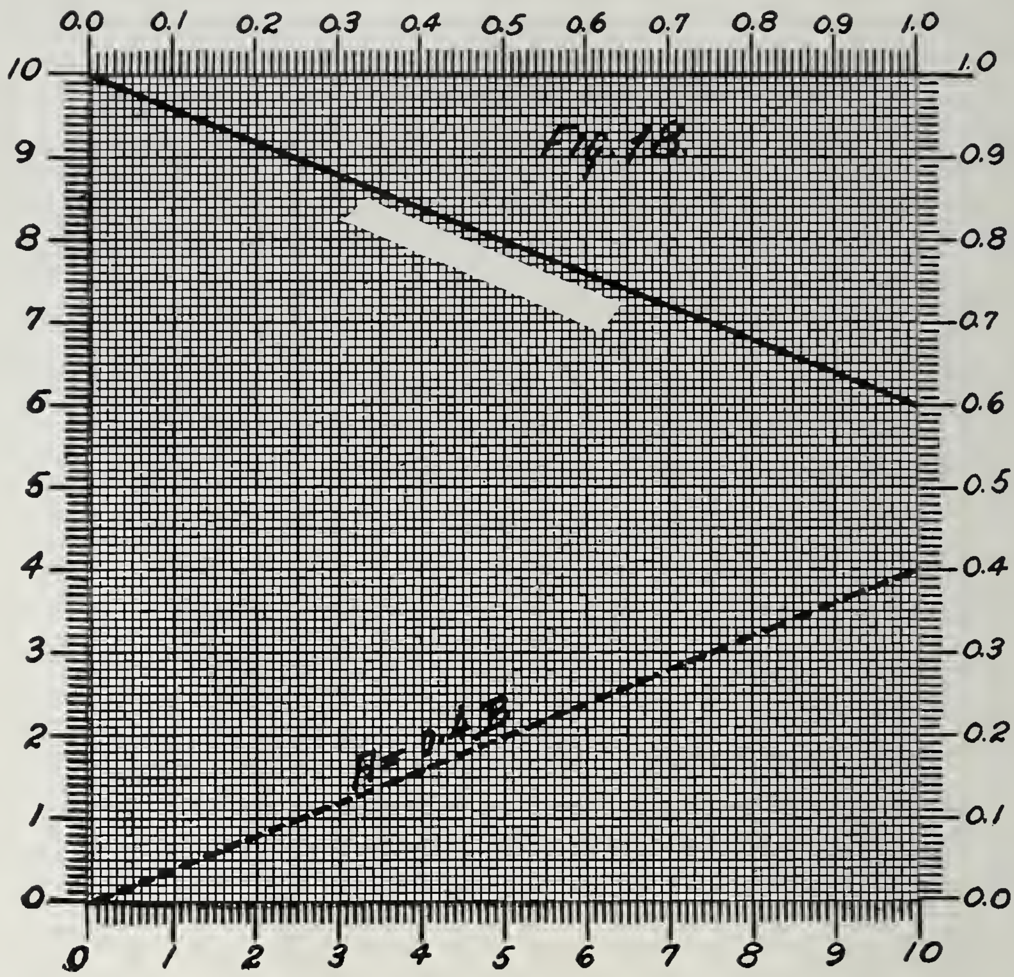


Fig. 18.
A = 0.4 B

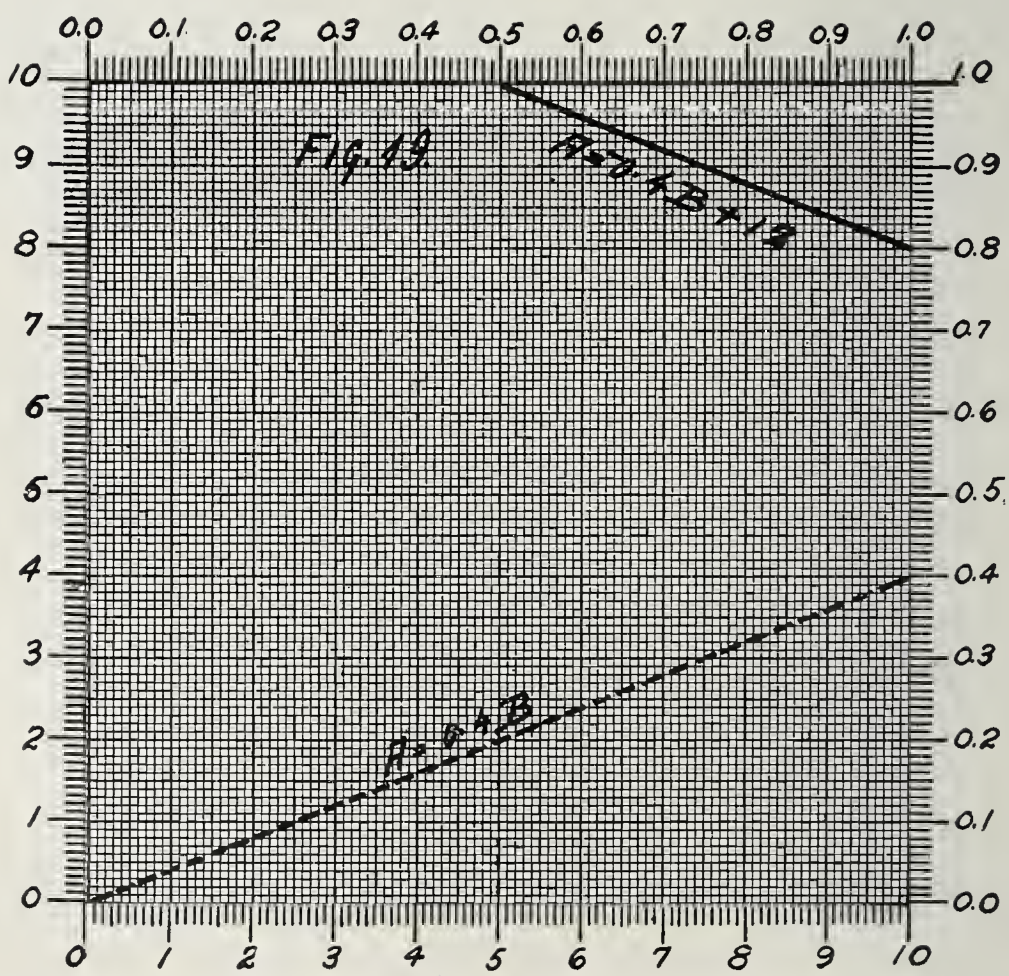
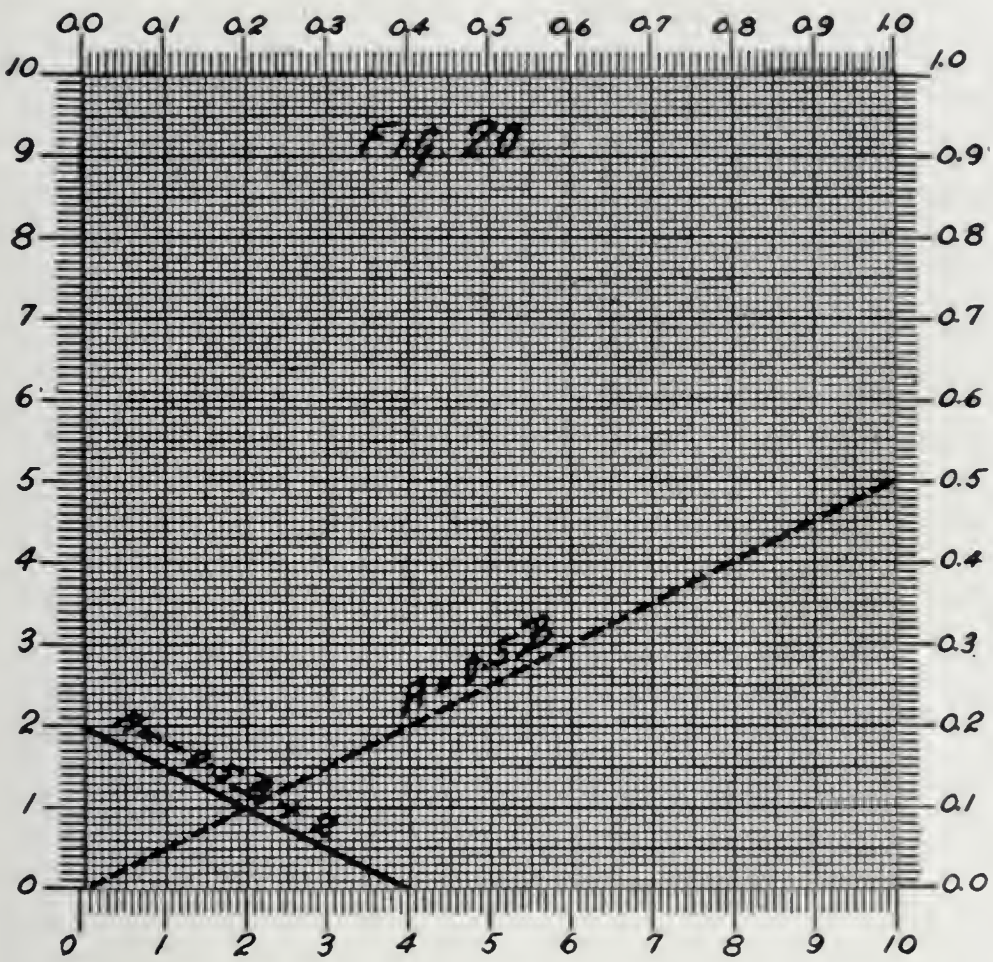


Fig. 19
A = 0.4 B + 10
A = 0.4 B

right scales will have a different value, 0 being at the upper right as shown in Fig. 22 with an example

$$A = -0.75\,B + 14.5$$

As this requires two sets of values for the top and right scales, the first method described with Fig. 6 is to be preferred.



25. Plain Paper Straight Line Characteristics. Résumé.

General Equation $A = \pm\, y\, B \pm z$

26. The primary characteristic is the line drawn through the observed values.

The secondary characteristic is a line drawn parallel to the primary, but passing through the left bottom zero. Whenever the primary has an inclination from left to right downward, the secondary passes through the left bottom zero from left to right upward at the same inclination to the horizontal as the primary.

27. $y = 1$ when the secondary intercepts the top or right scale at 1.

$y > 1$ when the secondary intercepts the top scale; its quantitative value is the reciprocal of the top scale intercept.

$y < 1$ when the secondary intercepts the right scale; its quantitative value is read directly from the scale intercept.

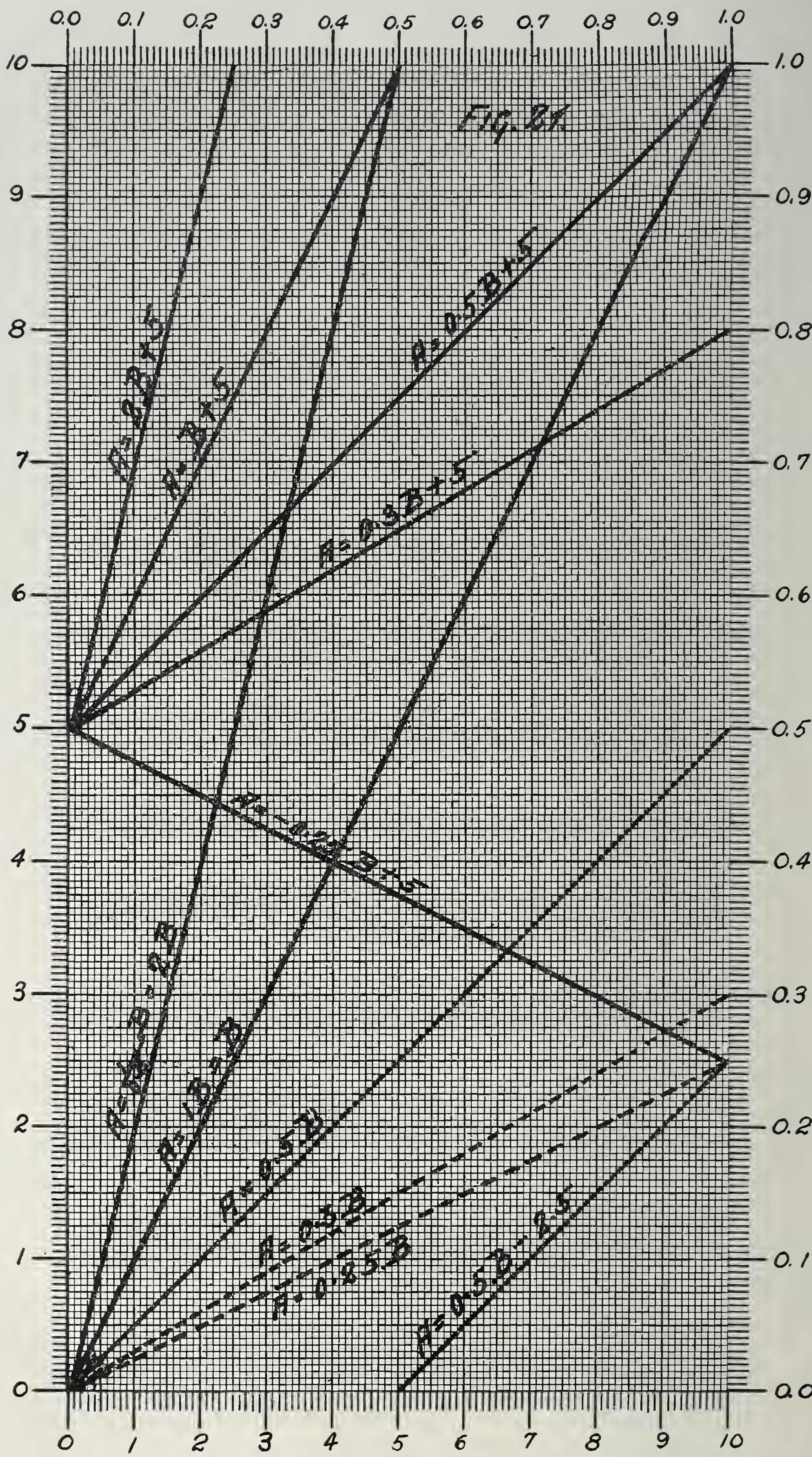


FIG. 2K
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 1 2 3 4 5 6 7 8 9 10
A = 2B + 5
A = B + 5
A = 0.5B + 5
A = 0.3B + 5
A = 2B
A = B
A = 0.5B
A = 0.3B
A = 0.25B
A = 0.5B - 2.5

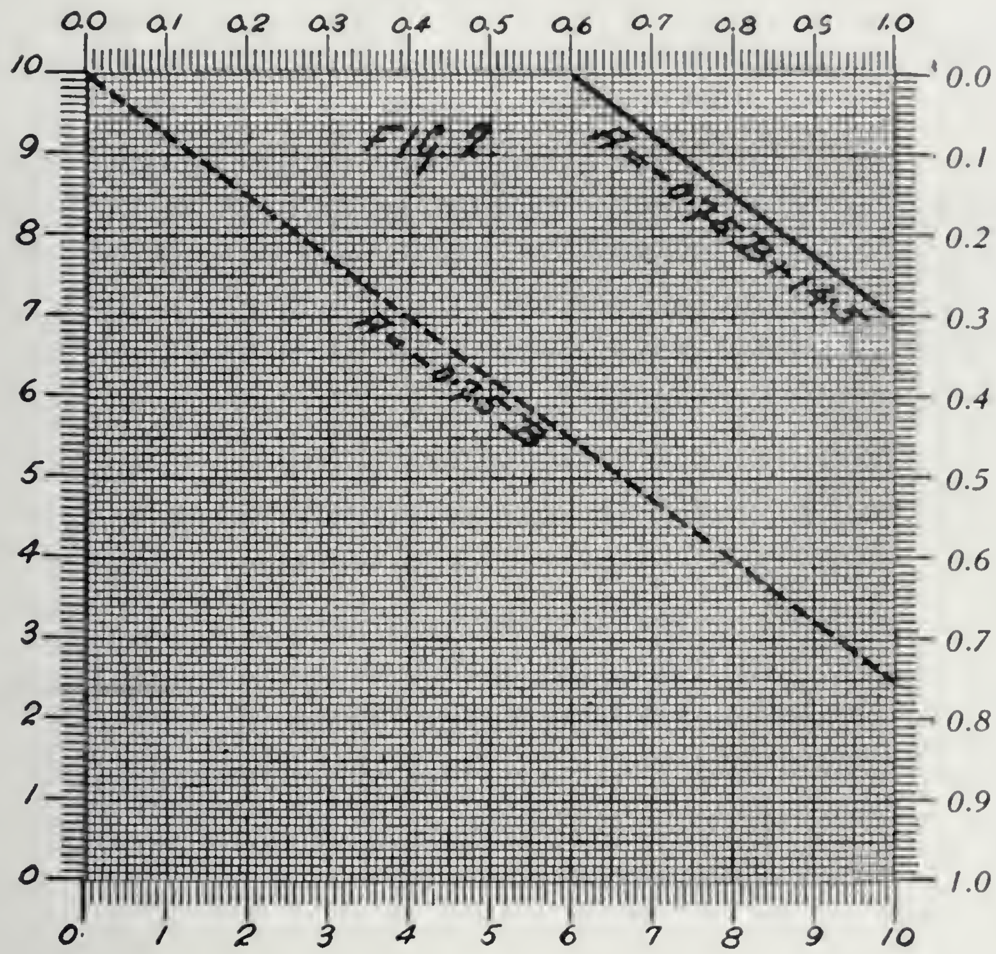
y is + when the characteristic rises from left to right.

y is — when the characteristic drops from left to right.

z has a quantitative value given by the intercept of the characteristic with the left scale, or of their prolongations.

z is + when the intercept is above 0.

z is — when the intercept is below 0.



LOGARITHMIC PAPER CHARACTERISTICS.

28. Logarithmic paper differs from plain paper only in the divisions being proportional to the logarithms of the number instead of proportional to the numbers themselves. For present purposes a familiarity with this paper is assumed.

29. Fig. 2 is a sheet of logarithmic paper differing from the ordinary only by the addition of the top and right scales of even divisions marked 1, 0.9, 0.8, etc., to 0. These correspond to those described in sections 3 and 15 for plain paper; but, whereas, with plain paper these new scales served to find the value of the coefficient y, they now serve to find the value of the exponent, x.

30. The general equation referred to in section 5

$$A = \pm y \, B^{\pm x} \pm z$$

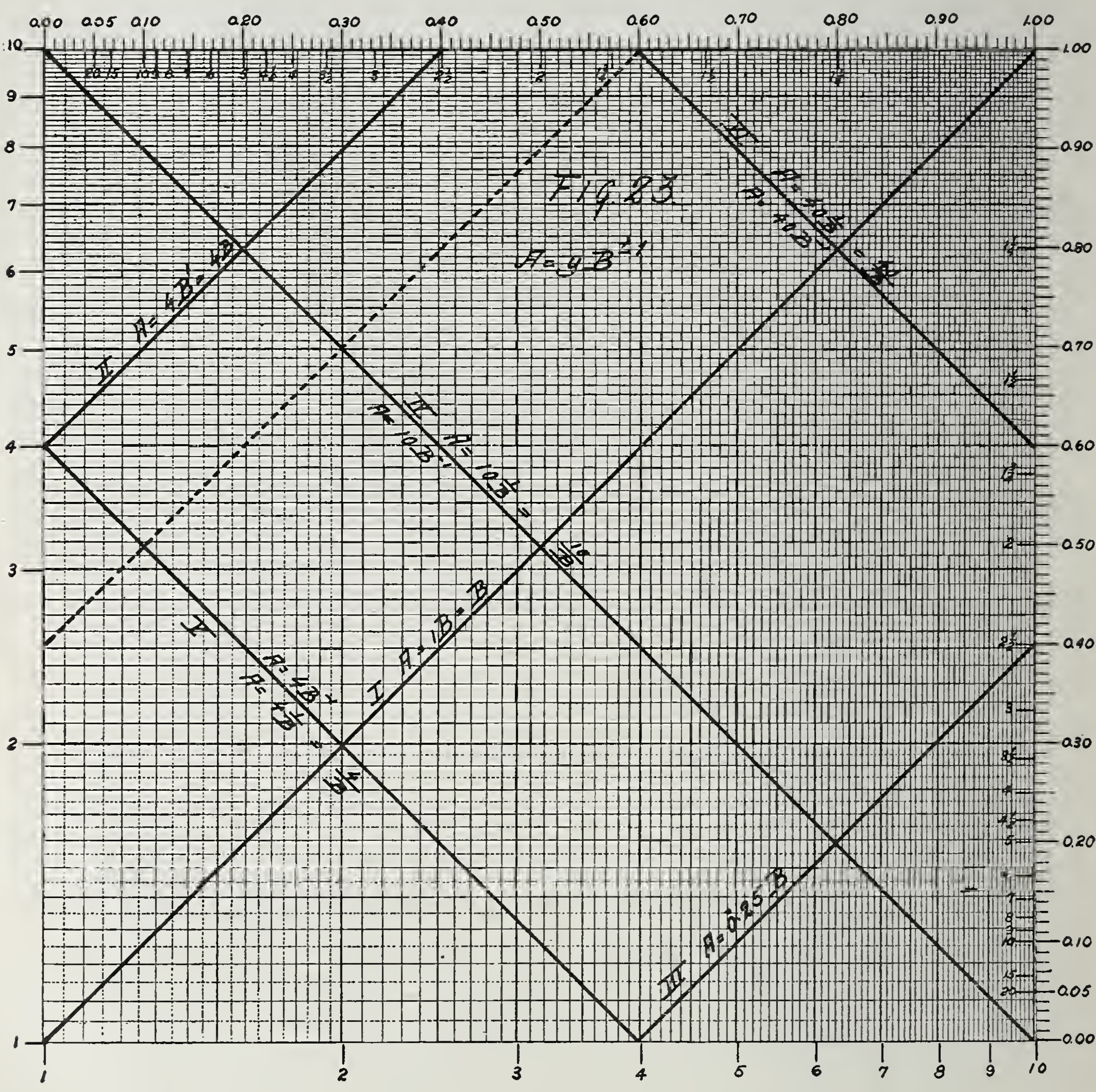
is conveniently handled by logarithmic paper and gives straight line characteristics whenever

$$z = 0$$

31. It is clear at once that all of the relations of Figures 3, 6, 9, 12, 15 and 18 which correspond to

$$A = \pm y B^{\pm x} \text{ with } x = 1$$

can be plotted on logarithmic paper as well as on plain.



32. This being so it would be logical to always plot data on logarithmic paper, because this covers far more ground than does the plain; unless indeed it were known that the relations correspond to

$$A = \pm y B \pm z$$

33. To avoid the multiplication of figures and as the proceedings are analogous to those explained in detail for plain paper, a number of characteristics are shown in Fig. 23, each marked with a Roman numeral.

34. The characteristic I starts from the origin 1 at left and bottom and intercepts the top scale at 1. This gives x as 1, or shows that the first power of B is involved.

As the characteristic trends from left to right upward, this shows that B is the numerator of a fraction whose denominator is 1.

As the characteristic intercepts the left scale at 1, this makes y = 1. We have therefore

$$A = 1\ \frac{B^1}{1} \text{ or } A = B$$

35. The characteristic II intercepts the left scale at 4, giving that as the value of y. The secondary parallel to the characteristic starts at left bottom 1; it coincides with I; this shows the exponent is 1 and the trend shows, as before, that B is $\frac{B}{1}$; this gives

$$A = \frac{4}{1}\ \frac{B}{1} \text{ or } A = 4\ B$$

36. The characteristic III (prolonged) intercepts the left scale (prolonged). Instead of prolonging the left scale, it will be convenient to dot in a second leg of III starting at the top vertically above the intercept with the bottom scale, in the manner usual with logarithmic paper, the second leg paralleling the first. The intercept of this line III a, with the left scale is at 2.5. As this is really the intercept of the prolongation of the left scale, which prolongation has values one-tenth those of the scale, the intercept value is 0.25, so that y = 0.25.

37. The characteristic IV trends from left to right downward; this means that B is the denominator of a fraction whose numerator is 1, or, expressed otherwise, the exponent x is minus.

The exponent is found, as before, by drawing in the secondary from left bottom 1 upward at the same inclination from the horizontal as the primary. This secondary coincides with I so that we know B is of the first power.

As the primary intercepts the left scale at 10 we have y = 10 and the total

$$A = \frac{10}{1}\ \frac{1}{B} \text{ or } A = 10\ B^{-1} \text{ or } A = \frac{10}{B}$$

38. The characteristics V and VI are similarly found to respond to

$$\text{V.}\quad A = \frac{4}{1}\,\frac{1}{B} \text{ or } A = 4\ B^{-1} \text{ or } A = \frac{4}{B}$$

$$\text{VI.}\quad A = \frac{40}{1}\,\frac{1}{B} \text{ or } A = 40\ B^{-1} \text{ or } A = \frac{40}{B}$$

39. The intercept of VI (prolonged) with the left scale is found by dropping the intercept at the top to the bottom and paralleling the characteristic to intersection with the left scale; it so happens that this coincides with line V. The intercept is at 4, but as the actual first intercept is above the scale this value must be multiplied by 10, giving 40. Had it been necessary to draw in a second prolongation, in case the first did not intercept the left scale then the multiplier would have been 100. In other words, each prolongation to final interception with the left scale multiplies the scale value by 10, if the true intercept falls above the scale; if that falls below the scale each multiplier becomes a similar divisor.

40. When, in the equation:

$$A = y\,B$$
$$y = 1 \text{ and } z = 0 \text{ we have}$$
$$A = B$$

Whenever the plotted values lie along a straight line characteristic that starts from the left bottom at 1, such characteristic responds to this equation. It remains only to determine the value of the exponent x.

41. It is here that the new top and right scales come in by making the determination of x a mere matter of reading the scale, such determination will be as simple when x is a compound fraction, as $1\frac{1}{3}$, as for the square, with x = 2.

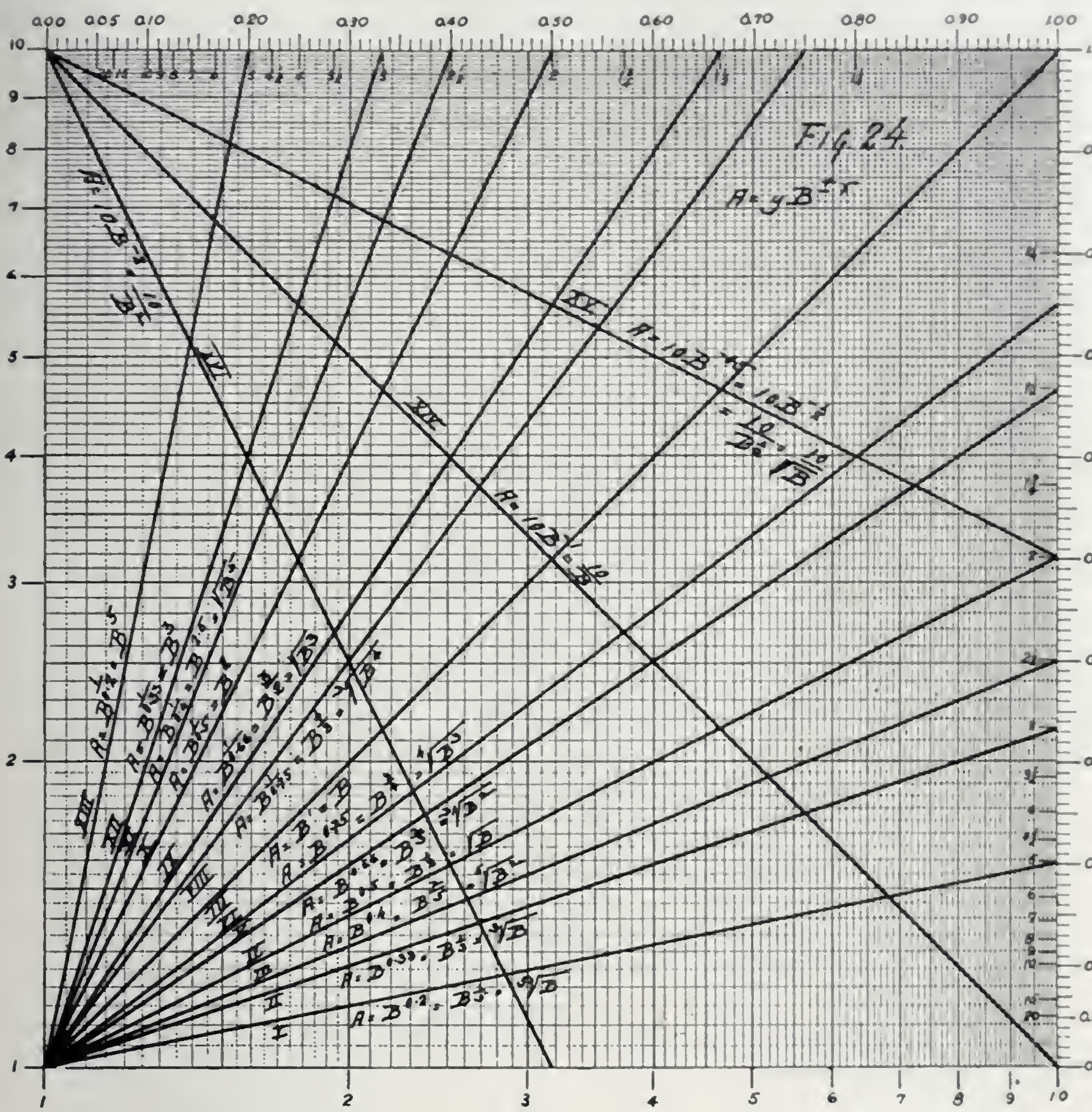
42. Whenever the characteristic intercepts the right scale the scale reading of the intercept is the power sought, and such power is less than 1.

Thus characteristic (Fig. 24):

I intercepts right scale at 0.2	and $A = B^{0.2}$	$= B^{\frac{1}{5}}$	$= \sqrt[5]{B}$
II " " " " 0.333	" $A = B^{0.333}$	$= B^{\frac{1}{3}}$	$= \sqrt[3]{B}$
III " " " " 0.4	" $A = B^{0.4}$	$= B^{\frac{2}{5}}$	$= \sqrt[5]{B^2}$
IV " " " " 0.5	" $A = B^{\frac{1}{2}}$	$= \sqrt{B}$	
V " " " " 0.666	" $A = B^{\frac{2}{3}}$	$= \sqrt[3]{B^2}$	
VI " " " " 0.75	" $A = B^{\frac{3}{4}}$	$= \sqrt[4]{B^3}$	

43. The characteristic intercepting the junction of top and right scales at 1 on scale gives

$$\text{VII.}\quad A = B^1 = B$$



44. Whenever the characteristic intercepts the top scale the reciprocal of the scale reading of that intercept is the power sought and such power is greater than 1. Thus characteristic

VIII intercepts top scale at 0.75 and $A = B^{\frac{1}{0.75}} = B^{\frac{4}{3}} = \sqrt[3]{B^4}$

IX " " " " 0.666 and $A = B^{\frac{1}{0.666}} = B^{\frac{3}{2}} = \sqrt{B^3}$

X " " " " 0.5 and $A = B^{\frac{1}{0.5}} = B^{\frac{2}{1}} = B^2$

XI " " " " 04. and $A = B^{\frac{1}{0.4}} = B^{\frac{5}{2}} = \sqrt{B^5}$

XII " " " " 0.333 and $A = B^{\frac{1}{0.333}} = B^{\frac{3}{1}} = B^3$

XIII " " " " 0.2 and $A = B^{\frac{1}{0.2}} = B^{\frac{5}{1}} = B^5$

45. The determination of the lower whole powers, such as the square and cube or the corresponding roots is a relatively simple matter by a trial calculation or two. The determination of such a relatively frequent exponent as $\frac{2}{3}$ or $\frac{3}{2}$ is by no means simple unless such value is expected and even then proof calculations entail much more trouble than does the use of these top and right scales. With these scales, on the other hand, a fractional power such as 0.666 or 1.333 is no more difficult than the simplest powers, as the square or cube or the corresponding roots.

46. Characteristics XIV to XVI of Fig. 24 correspond to the general form

$$A = \pm y B^{\pm x} \pm z$$

$$A = \pm y B^{\pm x}$$

with z = 0 so that

By the method of section 27, y = + 10.

As the trend of the characteristics is *downward* from left to right x is minus giving us

$$A = 10 B^{-x}$$

The value of x is determined by drawing in the secondaries, that in this case correspond to characteristics III, IV and X giving x = 1, 0.5 and 2 so that

$$\text{XIV is } A = 10 B^{-1} = \frac{10}{B^1} = \frac{10}{B}$$

$$\text{XV is } A = 10 B^{-0.5} = \frac{10}{B^{0.5}} = \frac{10}{B^{\frac{1}{2}}} = \frac{10}{\sqrt{B}}$$

$$\text{XVI is } A = 10 B^{-2} = \frac{10}{B^2}$$

47. Fig. 25 contains a group of characteristics again responding to the general form

$$A = \pm B^{\pm x} \pm z$$

but that have values for z other than 0.

48. Reversing the process of finding the expression from plotted data take the dotted secondary I.

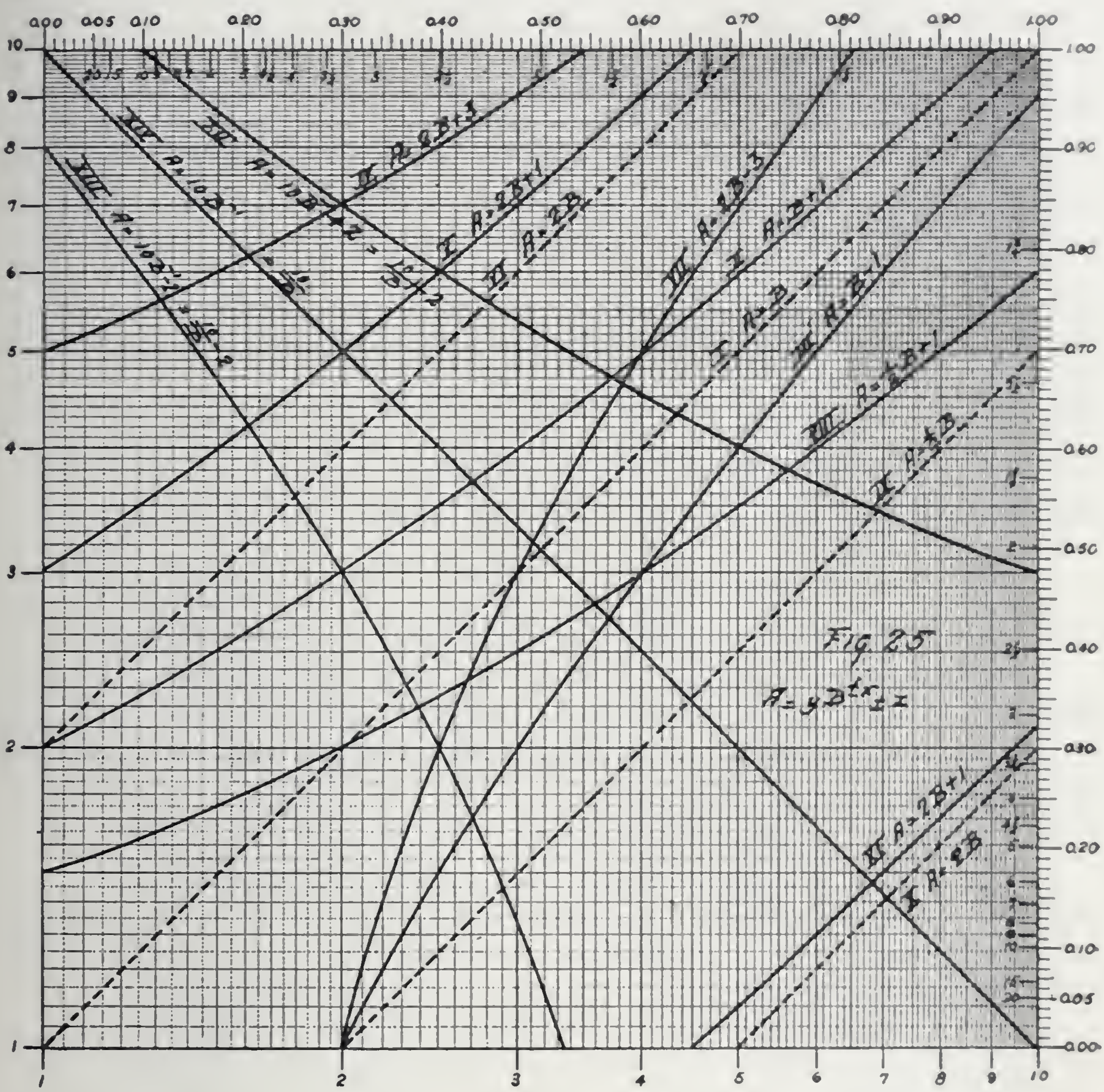
This is A = B. Adding z = 1 gives characteristic II

$$A = B + 1.$$

In adding z the logarithmic scale value of z corresponding to that portion of the paper in question must be taken, so that with the *logarithmic* paper the characteristic becomes a curve. On plain paper (section 9) with B in the 1st power, the characteristic was a straight line. To formulate observations which, plotted, give the character-

istic II, the first proceeding is to draw a secondary from the left bottom 1 to the right top 1; if inspection at two points shows that to be an equal amount below the characteristic such amount is z.

It must not be overlooked that it is not the scale value of the intercept at the left which equals z, but the distance between the character-



istic and its secondary; this is the vertical difference between any two points.

49. Characteristic III A = B — z differs from II only in lying *below* its secondary I by the amount z, so that z is minus.

50. The determination of the sign + or — for z is simple by mere inspection: If the characteristic is above its secondary, z is +; if the characteristic is below its secondary, z is —.

51. Characteristic IV plotted through observed data is assumed by inspection to be of the general form

$$A = \pm y B^{\pm x} \pm z$$

Mere inspection shows (characteristic above its secondary) that z is + (Section 50); inspection also discloses, since the trend is upward from left to right, that x is +. The values of y, x and z remain to be found. The simplest assumption is that x = 1 and that y = 1. In that case the dotted I would be the secondary; also I would be equidistant from IV; examination shows that at the left scale the difference between IV and I is 5 — 1 = 4, while over 3 on the bottom scale this difference is 9 — 3 = 6; as these differences are not equal our assumption was incorrect. Still working along the simplest lines we will assume that x is still 1, but that the y is some value larger than 1. Then moving a 45 degree triangle upward gives a position at which the differences z are equal; in this case z = 3 for the secondary VI. This straight line secondary is A = y B with y — 2 from its intercept with the left scale (Section 35). This gives us

$$A = 2B + 3$$

52. Characteristic V is similarly found to be A = 2 B + 1.

53. Characteristic VII being below its secondary gives z as minus. Proceeding by trial as in Section 51 gives the secondary VI A = y B at distance z = 3; as y = 2 (by left intercept) A = 2 B; the total for characteristic VII is

$$A = 2B - 3$$

54. Characteristic VIII being above its secondary gives z as + and = 1. Proceeding by trial we get the secondary IX, which in the familiar way is resolved into

$$\text{IX.} \quad A = \frac{1}{2} B \quad \text{making}$$

$$\text{VIII.} \quad A = \frac{1}{2} B + 1$$

55. The method of forming continuations of these characteristics is of interest. Take

$$\text{V.} \quad A = 2B + 1$$

Continue first the characteristic VI. A = 2 B and get — X; by adding z = 1 to this we get

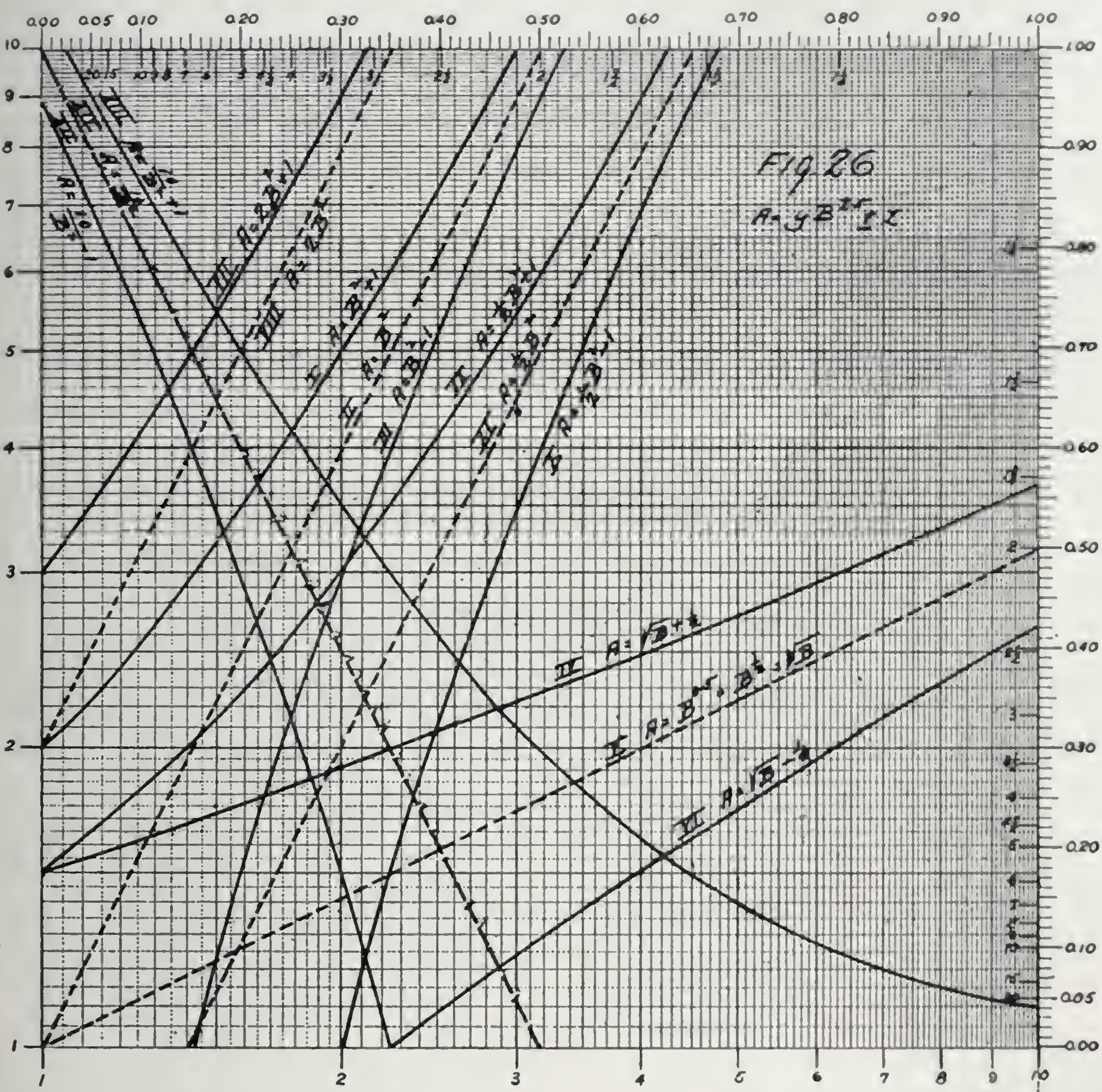
$$\text{XI.} \quad A = 2B + 1$$

As this continuation is a second leg the scale values of the first part

are increased tenfold, so that the distance that for the first section was 0.1 is now 1.

56. Characteristics XII and XIII trending from left to right downward show by inspection that the exponent x is —.

XII being above its secondary shows that z is + while XIII being below shows that z is —.



Proceeding as before on the simplest assumption that x = 1, we get the secondary XIV for both characteristics and from its intercept with the left scale at 10 find y = 10; z was found by trial as being 2 above the secondary for XII and 2 below for XIII, giving totals

$$\text{XII.} \quad A = y\,B^{-1} + z = \frac{10}{B} + 2$$

$$\text{XIII.} \quad A = y\,B^{-1} - z = \frac{10}{B} - 2$$

57. Plotting a series of observations gives a characteristic I on Fig. 26. We assume that this is still of the general form

$$A = \pm y B^{\pm x} \pm z$$

The elevation above secondary shows z is +; we therefore move a straight edge around below the characteristic until a line, II, is found that is equidistant by the amount $z = 1$. This secondary has its origin in the left bottom 1 and intercepts the top scale at 0.5 showing that $x = \frac{1}{0.5} = 2$; as the trend is from left to right upward x is +.

This gives the Secondary II $A = B^2$ and the
characteristic I $= B^2 + 1$

58. The characteristic III is similarly determined as $A = B^2 - 1$, remembering that z must be — since the characteristic is below its secondary.

59. Characteristics IV and VI are readily found to have the secondary V, whose exponent is given by intersection with the right scale as $x = 0.5$ making

Secondary V. $A = B^{\frac{1}{2}} = \sqrt{B}$ and
Characteristic IV. $A = \sqrt{B} + \frac{1}{2}$
Characteristic VI. $A = \sqrt{B} - \frac{1}{2}$

The values of z were found as the difference between the characteristics and their secondary.

60. Characteristic VII. $A = 2 B^2 + 1$
Secondary VIII. $A = 2 B^2$
Characteristic IX. $A = \frac{1}{2} B^2 + 1$
Characteristic X. $A = \frac{1}{2} B^2 - 1$
Secondary XI. $A = \frac{1}{2} B^2$

are readily determined by the aid of the preceding explanations.

61. Characteristics XII. $A = 10 B^{-2} - 1 = \frac{10}{B^2} - 1$
Characteristics XIII. $A = 10 B^{-2} + 1 = \frac{10}{B^2} + 1$
Secondary XIV. $A = 10 B^{-2} = \frac{10}{B^2}$

will be readily determined, remembering that the elevation of XIII above its secondary establishes z as + and the depression of XII

gives its z as —; also that the downward trend from left to right fixes x as —, while the value of x is fixed by the intersection of the secondary's complement II with the top scale at 0.5, the reciprocal of which, 2, gives x.

Résumé

62. General Equation $A = \pm y B^{\pm x} \pm z$

If the plotted characteristic is a straight line z = 0 leaving

$$A = \pm y B^{\pm x}$$

63. If the plotted characteristic is a straight line trending from left to right upward x will be plus, if downward x will be —.

64. If the plotted characteristic is a straight line crossing the paper at an angle of 45 degrees x will be 1.

65. If the plotted characteristic is a straight line nearer the vertical x will be greater than 1; if nearer the horizontal x will be less than 1.

66. If the plotted characteristic is a straight line passing from left to right upward from the lower left origin, y will have the value of origin 1.

67. If the plotted characteristic is a straight line passing from left to right upward from the lower left origin, 1, its intercept with the upper scale will be at a value that is the reciprocal of x; if the intercept is with the right scale the intercept value will be x as a power; the reciprocal of x will be a root.

68. If the plotted characteristic is a straight line its intercept with the left scale will give y. If it does not intercept the left scale then the intercept of its prolongation with the prolongation of the left scale will give y. If such intercept is with the downward prolongation of the left scale y will be less than 1; if with the upward prolongation y will be greater than 1.

69. If the plotted characteristic is a straight line downward from left to right then x will be —. Its value is found by drawing a secondary that runs upward from left to right through the lower left origin, 1, at the same inclination from the vertical as the primary. This secondary will intercept the top or right scales and there give values of $^{\pm x}$ (Section 37).

70. If the plotted characteristic is a straight line trending upward from left to right and intercepting directly or by prolongation the left scale at some value other than the lower left origin, 1, then a

secondary drawn through that origin and parallel to the characteristic will, by its interception with the top or right scale, give the value of $\pm x$.

71. If the plotted characteristic is a curved line, z will have a value other than 0. z will be + if the characteristic is above the secondary; z will be — if the characteristic is below the secondary.

72. If the plotted characteristic is a curved line z will have a value the amount of which must be found by drawing in a secondary. This may be done by maneuvering a straight edge around on the convex side of the characteristic until a position is found which is equidistant throughout (on vertical logarithmic scale) from the characteristic. This distance is z.

73. If the characteristic is a curved line the value of z will be the vertical scale difference between the characteristic and its secondary.

The first secondary is that straight line which lies at equal vertical distances from the characteristic.

74. If the characteristic is a curved line the value of y will be given by the intercept of its first secondary with the left scale.

75. If the characteristic is a curved line the value of x will be given by the intercept of the second secondary with the top or right scales.

The second secondary is a straight line passing through the left lower origin and parallel to the first secondary.

In conclusion it is hoped that this presentation of one phase of a subject that is capable of being made a far more useful tool to the busy engineer generally will lead to an extension of its conveniences to cover other general expressions likely to come up in the practice of engineers in various special lines.

DISCUSSION.

Carl Hering.—Perhaps it may not be generally known that there is a very simple way of testing the accuracy of the spacing of cross-section paper of the usual kind in which the spaces are intended to be equal. If a piece of such paper be held in a stereoscope so that the vertical lines seen by one eye become superimposed upon different vertical lines seen by the other eye, then if the horizontal spacing is accurate the paper will look flat; but if the spacings are not all equal, some of the vertical lines will appear to be nearer to the eye and others farther off, due to the stereoscopic effect produced by the stereoscope; in other words, there will be a perspective effect and the lines will look like a series of stretched strings which are not all in one plane. This test applies only to the vertical lines; to apply it to the horizontal lines the paper must be turned so that they become

vertical. A cheap quality of paper in which the spacing is not accurate presents quite an interesting appearance in the stereoscope, sometimes appearing like a series of steps viewed from above. With a little training it becomes very easy to make this test without any stereoscope by forcing each eye to look at a different group of lines and then adjusting the eyes so that these lines become superimposed. This becomes easier to the untrained eye if a hole is cut in a piece of paper held between the eye and the cross-section paper, then looking at the latter with both eyes, through the hole; each eye will thereby be shielded from the lines seen by the other eye. By moving the paper with the hole in it nearer to, or farther away from the eyes, different sets of lines may be easily superimposed, thus different parts of the latter may be tested. Instead of a piece of paper with a hole in it, a strip of paper may be used, or the finger may be held before the eyes so as to shield from each eye the lines seen by the other. A little training enables one to do this without any intervening shield. Of course, only vertical lines can thus be tested, and they should be held quite vertically; if they slant to the right or left, the eyes cannot adjust themselves.

Logarithmic paper when examined in this way ought theoretically to give the appearance of lines on a regularly curved surface, curving away from or toward the eye, as the case may be. If not accurately spaced, the appearance will be that of a series of lines at irregular distances from the eye, like the trees along the edge of a woods looked at diagonally. This is the way they appear in Fig. 23, p. 170, which proves to be very inaccurate.

President Spangler.—The use of logarithmic paper is probably more common abroad than among engineers in this country. Here are some samples of such paper, made in France, and very inexpensive.

If one has not such paper at his command, the lower scale of an ordinary slide rule will do admirably to lay off the divisions for logarithmic paper, and one can manufacture paper that will answer most purposes very easily.

A special form of slide rule is manufactured which will make it practically unnecessary to plot observations that probably fall on a curve, the equation of which might be written in the form of $pv^n = K$.

By the use of this slide rule any power or root of a quantity can be written by simple inspection after one setting of the slide. The rule has, in addition to the usual divisions, a set of rulings along the upper and lower edge of the rule, laid off to represent the log. log. of the numbers to the same scale that the other divisions represent the log. of the numbers themselves, the numbers running from 1.1 to 10,000 on the top edge and on the bottom edge from .091 to .0001.

By the use of such a slide rule, and without plotting, the value of n corresponding to any pair of simultaneous observations can be written almost instantly and the average for all such observations is much more accurate than any drawing on the logarithmic paper might be.

When it comes to sketching in a curve on plotted values, the process is simply a method of guessing, and depends on one's skill at guessing whether a line might be right or wrong. You *assume* that it is a certain kind of curve, and then you guess at its position.

Of course, there is only one right way of determining the constants for an assumed character of curve to fit any series of observations, and that is by the method of least squares. If the work is done according to this method, the re-

sults are the most probable, granting that your assumed character of curve is the proper one. Or if one wishes to go into the matter more deeply, the same method of least squares will allow one to pick from several kinds the most probable kind of a curve.

That the selection of the constants for an equation is largely a matter of guess-work was illustrated in a quite well-known text-book some years since, where from edition to edition the values were changed several times, although the formula was based on exactly the same set of experimental results.

The use of the logarithmic paper is decidedly of value in permitting one to form an opinion as to whether the curve $pv^n = K$ at all fits the conditions or not. For instance, if one believes that the expansion line of an internal combustion engine is a line of this character, five minutes with logarithmic paper will probably convince one that the constants seem to vary decidedly from point to point.

Paper of the type here shown has a capacity of 100 to 1 each way, that is, horizontal readings or vertical readings, in which the largest is not over 100 times the smallest, can be used without modification. If the ratio is greater than this, the paper is difficult to use. As the author points out, the scales need not be the same vertically and horizontally; thus the horizontal values may vary from 80 to 2500, while the vertical may vary from 1.2 to 96, and all the values may be plotted without reduction.

If a series of observations pass through zero simultaneously, it is easy to note the successive values of n for the successive observations and average them, as the tangent of the line from the point of observation to the point 1.1 can be measured by an ordinary rule divided to tenths.

John C. Trautwine, Jr.—The author's proposed addition of scales, at the top and on the right of plain and logarithmic diagrams, is certainly useful, and is probably new. With the exception of occasional communciations in the engineering periodicals, and a couple of pages in Trautwine's "Civil Engineer's Pocket-Book," this paper seems to constitute about all of the existing literature on the subject of such diagrams, and information as to what has been done in connection with them is correspondingly limited.

The author is particularly to be complimented upon his ingenuity and enterprise in undertaking to show us the color of his printed sheets by means of lantern slides made by the Lumière process. That the results of the first venture in this direction proved less successful than was hoped, is only typical of worthy effort in general.

Any criticism of Mr. Hess's paper that might be offered would be chiefly in regard to the method of arrangement.

If he had stated, near the outset, that his added scales give, with "cross-section" paper, the value of his y (usually denoted by c), and, with logarithmic paper, the value of his x (usually denoted by n), it would have saved much reading for the purpose of discovering the office of these scales; but then, as Mr. Hess remarks, it would have defeated his purpose by cutting short my reading of the paper.

I may also be permitted to criticize Mr. Hess's compliance with the custom of applying the term "logarithmic *cross-section* paper" to the logarithmic chart or diagram. This custom beautifully illustrates the methods by which we obtain our terminology. When drawing-paper, ruled in squares, was first introduced,

the practice of studying results by means of diagrams, with abscissas and ordinates, was probably but little used; and the ruled paper found its chief use among railroad draftsmen, who found it convenient for drawing cross-sections of their roadways, chiefly in the process of calculating quantities of earthwork. Hence the name, "cross-section paper." Today, probably, the use of such paper for the plotting of experimental results far exceeds its use for cross-sectioning; yet the old name, referring to what is now a minor use, persists; and this is all very well, for the name is convenient and not seriously misleading. But it is manifestly absurd to apply the name "cross-section paper" to paper ruled *logarithmically*, upon which, I venture to say, no draftsman could satisfactorily plot a cross-section, except by ignoring the ruled lines.

In the absence of adequate literature, each user of cross-section and logarithmic paper is left to his own devices. The author has kindly explained one of his, and some proposed by others may be of interest.

Years ago, Mr. John R. Freeman engraved and published two logarithmic charts, handsomely and carefully lithographed, twenty inches square; one giving a single logarithmic square, with scale of 20 inches, the other four complete squares, with scales of 10 inches each.

These are admirably adapted to any work which requires all the accuracy which can be expected from such diagrams; but they necessarily limit one to a choice between two scales; and, where the operation extends through several decades, they may necessitate several re-crossings of the sheet.

Great convenience may be found in using plain "cross-section" paper logarithmically, *i. e.*, finding, by means of a table, the logarithms of the quantities to be plotted, and plotting these logarithms upon plain cross-section paper, decimally divided, as indicated in Fig. 1 (b).

Figs. 1 (a) and (b) illustrate the plotting of a supposed series of experiments to obtain the velocity of a falling body by means of the observed heights through which it has fallen at the ends of measured times, from one to ten seconds.

The experiments are supposed to have given the heights shown, under h, in the table on the left, and plotted first to natural scale, as shown in Fig. 1 (a). Through the points, so obtained, we may draw a curve, as shown, but this gives us no certain information as to the equation of the curve.

But, still using cross-section paper, Fig. 1 (b), I take, from a table, the *logarithms* of the three series of quantities shown on the left, tabulate them, as on the right, and then plot these logarithms upon "cross-section" paper, following the scales of logarithms there shown. This, of course, gives the same diagram, as if the *times, velocities, and heights themselves* were plotted upon *logarithmic* paper.

We now find the experiments approximating a straight line, which, *if correctly drawn*, gives us the equation desired. Here the dotted "secondary" (see author's paper), starting from the origin, at the lower left-hand corner, intercepts the right-hand scale at 2.0, showing that the exponent is 2, or that the heights, through which the body has fallen, are proportional to the *squares* of the times.

It will be noticed that this "secondary" cuts the top of the lower diagram at 0.5 of the author's scale, 0.5 being the reciprocal of 2.0.

The characteristic itself cuts the left-hand vertical at 16.1, so that the equation stands: $h = 16.1\ t^2 = \frac{g}{2}\ t^2$.

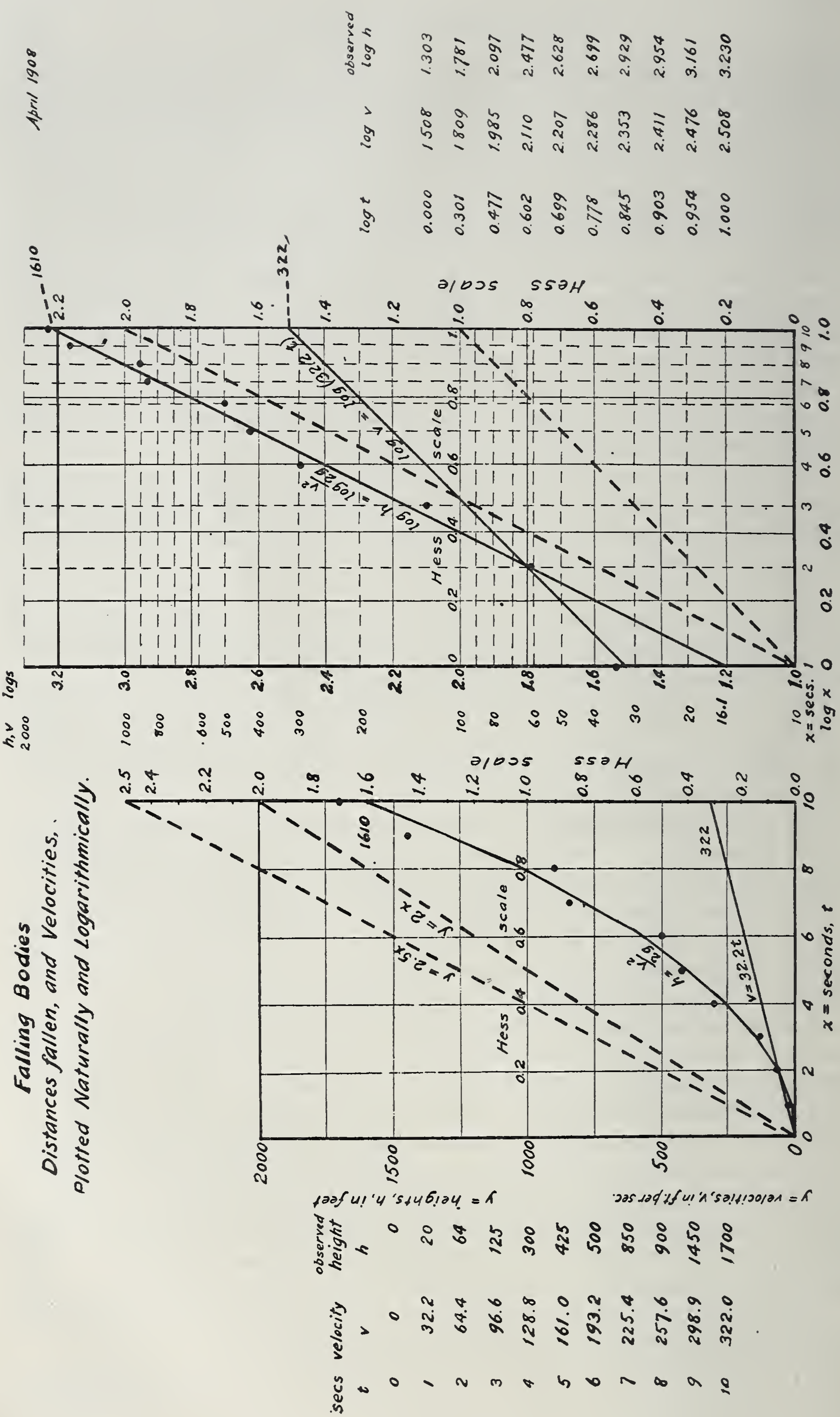

Falling Bodies
Distances fallen, and Velocities,
Plotted Naturally and Logarithmically.
April 1908
secs t | velocity v | observed height h
0 | 0 | 0
1 | 32.2 | 20
2 | 64.4 | 64
3 | 96.6 | 125
4 | 128.8 | 300
5 | 161.0 | 425
6 | 193.2 | 500
7 | 225.4 | 850
8 | 257.6 | 900
9 | 298.9 | 1450
10 | 322.0 | 1700
y = heights, h, in feet
y = velocities, v, in ft. per sec.
x = seconds, t
v = 32.2t
h = g/2 t²
y = x
y = 2.5x
Hess scale
1610
322
h, v
logs
x = secs.
log x
log h = log g/2 t²
log v = log (32.2t)
log t | log v | observed log h
0.000 | 1.508 | 1.303
0.301 | 1.809 | 1.781
0.477 | 1.985 | 2.097
0.602 | 2.110 | 2.477
0.699 | 2.207 | 2.628
0.778 | 2.286 | 2.699
0.845 | 2.353 | 2.929
0.903 | 2.411 | 2.954
0.954 | 2.476 | 3.161
1.000 | 2.508 | 3.230

Fig. 1.

Having thus obtained the theoretical value of h, we readily obtain the corresponding values of v by means of the formula: $v = \sqrt{2 g h}$. In both figures, the (straight) line for v cuts the right-hand vertical (t = 10 seconds) at 322 feet per second.

In the left-hand figure, Fig. 1 (a), we have taken different scales for the horizontal and vertical distances. Hence, as explained in the author's paper, his added

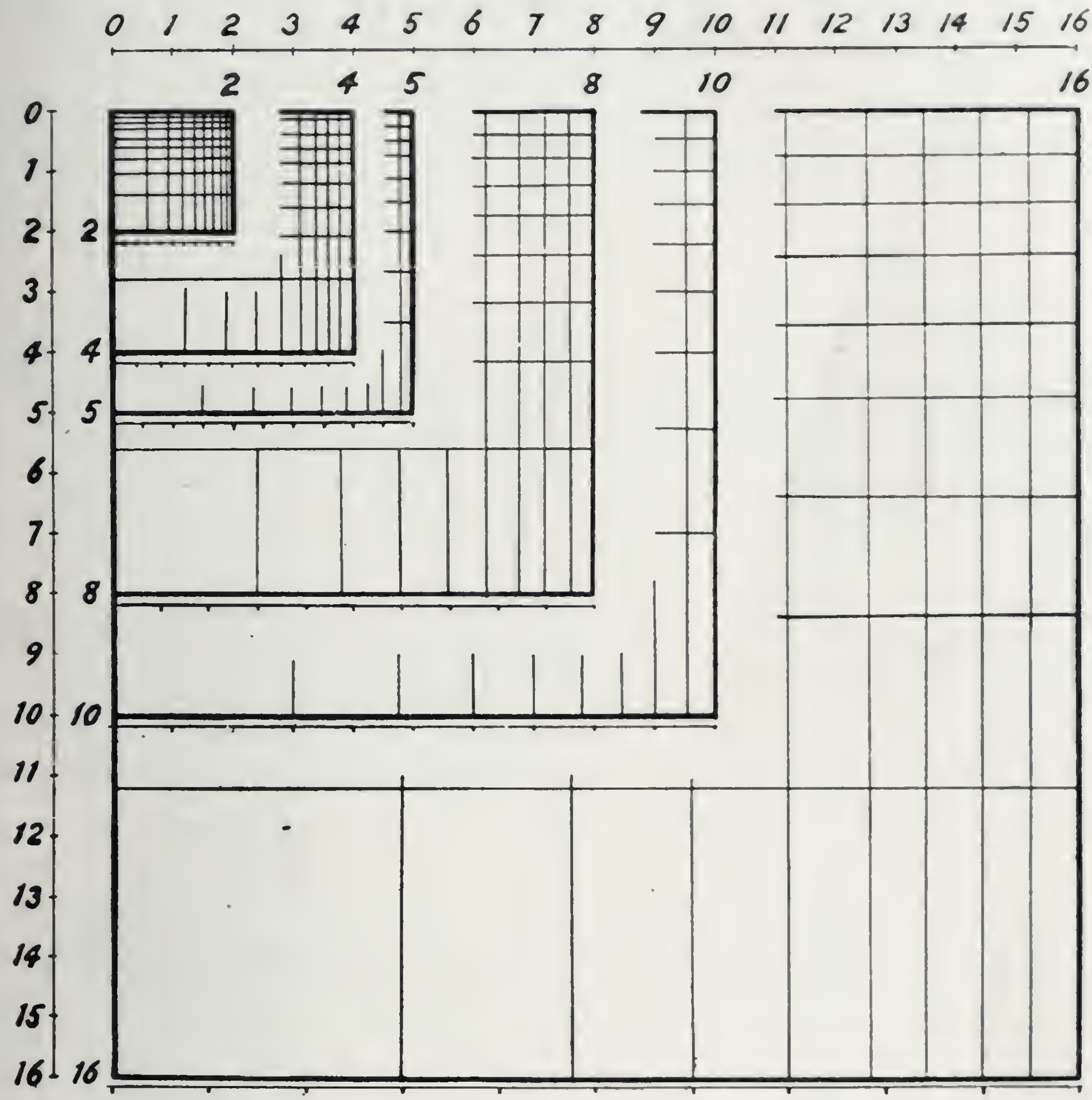


Fig. 2.

horizontal and vertical scales are correspondingly different. The dotted line, y = 2 x, starting from the origin, cuts the right-hand vertical at 2.0, and Mr. Hess's top scale at $0.5 = \frac{1}{2.0}$ while line y = 2.5 x cuts the right-hand vertical at 2.5, and the author's top scale at $0.4 = \frac{1}{2.5}$. These two lines have no reference to the supposed experiments here represented, and are added merely as a further illustration of the principle of the author's modification.

In both figures, the *solid* vertical and horizontal lines represent the equi-

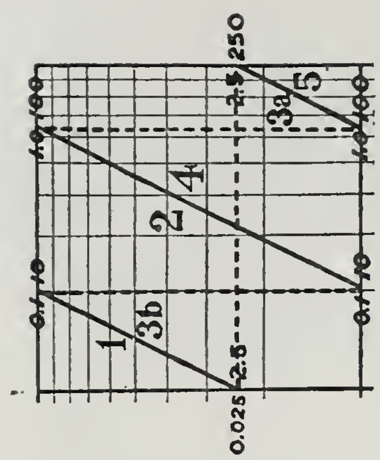


Fig. 3-c.

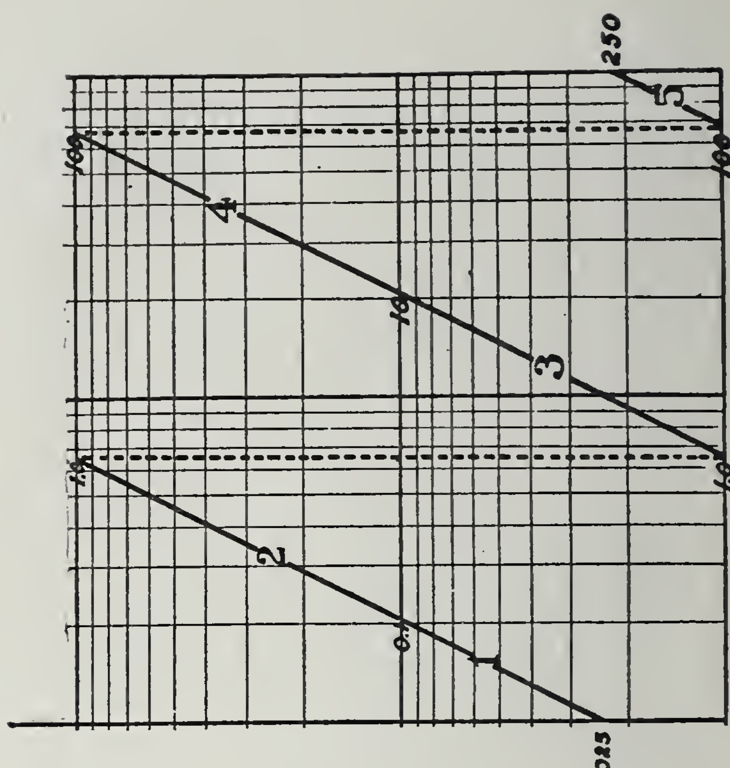


Fig. 3-b

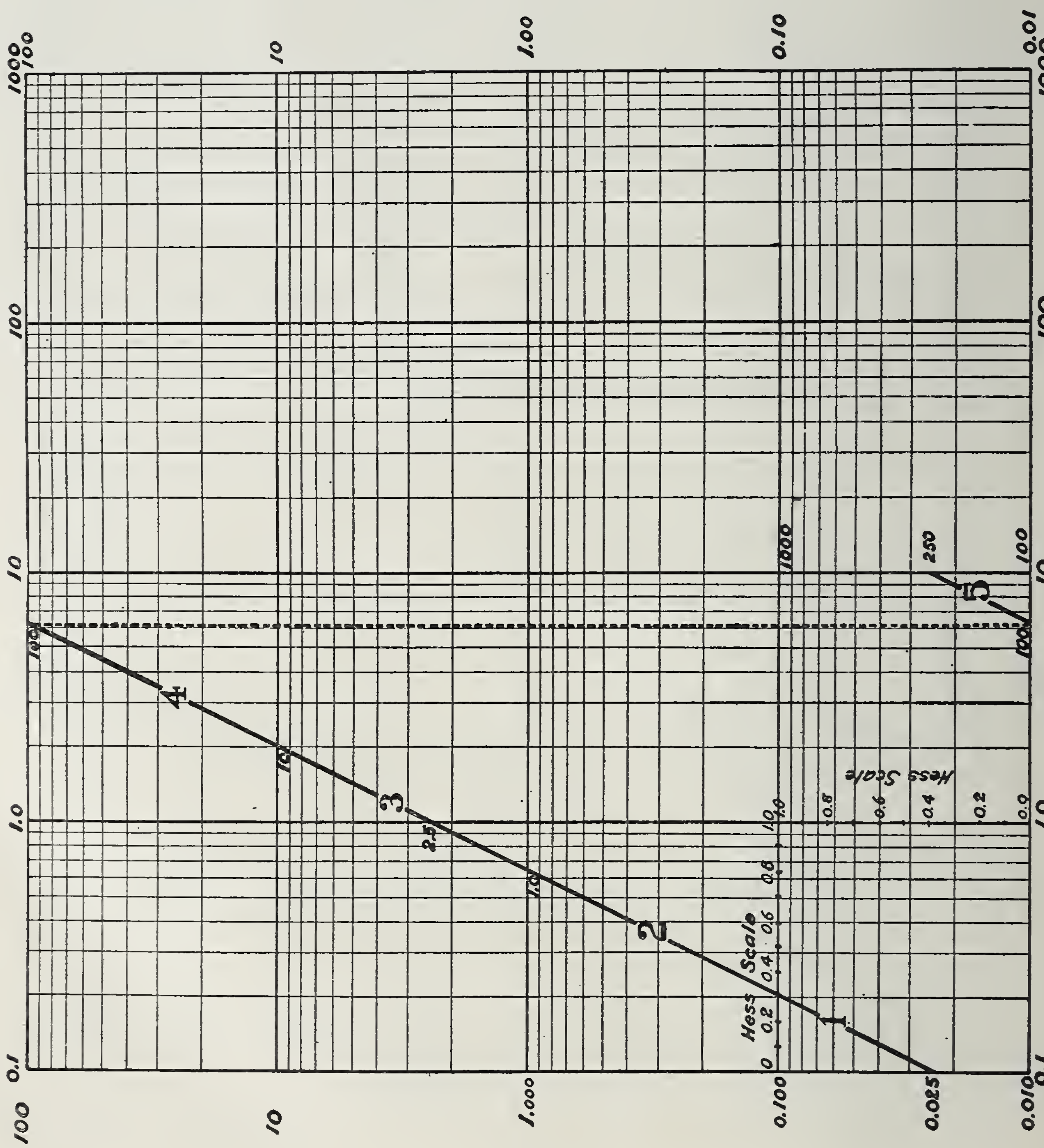


Fig. 3-a

distant rulings of the "*cross-section*" paper used, while, in the right-hand figure, the *dotted* vertical and horizontal lines show where the corresponding rulings of the *logarithmic* paper would lie.

A great advantage, of this use of "cross-section" paper for logarithmic plotting, is that it gives us a large assortment of logarithmic scales to select from, as shown in Fig. 2, which represents a sheet of "cross-section" paper 16 inches square, divided into inches and tenths, upon which, as shown, we might conveniently find six logarithmic scales, namely: 2″, 4″, 5″, 8″, 10″, and 16″.

In cases where one or both quantities range through a considerable number of decades, it frequently happens that our principal object is the study of the relations between the quantities, and great accuracy is not required. In such cases it is convenient to select a small logarithmic scale (a selection rendered easy by plotting logarithmically upon "*cross-section*" paper), so that we may place a

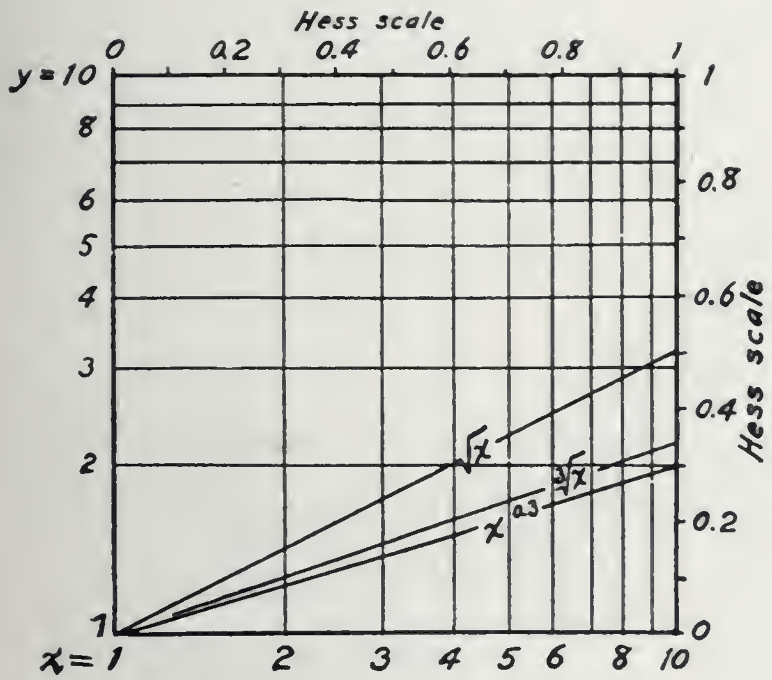


FIG. 4a.

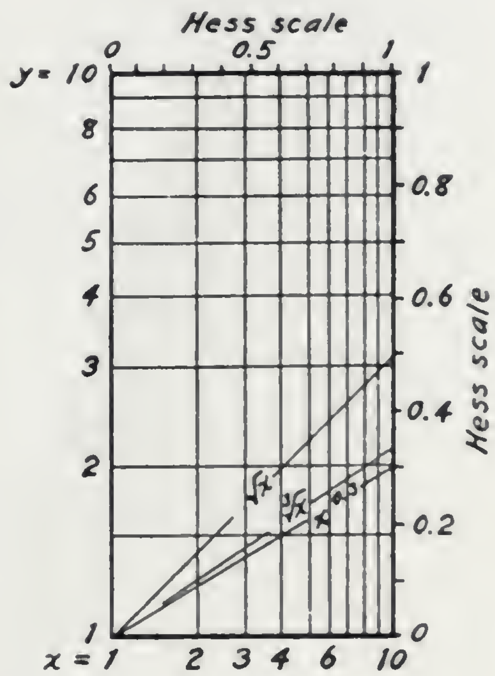


FIG. 4b.

considerable number of scales upon the same sheet, as indicated in Fig. 3 (a), which shows a square sheet composed of sixteen small squares, upon which we have plotted a diagram, representing the equation $y = 2.5\ x^2$, with values of x ranging from 0.1 to 10, and values of y therefore from 0.025 to 250. This diagram is divided into five sections, numbered 1, 2, 3, 4, and 5, for comparison with the figures on the right. (See below.) In order to draw section 5, we have to cross the sheet once vertically from top to bottom as per dotted line.

On the right, below, Fig. 3 (b), we have a reproduction (to reduced scale, and showing only the principal lines) of Mr. Freeman's 20-inch chart, with four 10-inch scales. Here we must first cross the chart diagonally, from bottom to top, with the first portion of the line (sections 1 and 2). Then we drop to the bottom (see dotted vertical line), and recross the chart diagonally with sections 3 and 4. Then, again, as in Fig. 3 (a), we cross the sheet vertically, in order to draw section 5.

The upper figure, on the right, Fig. 3 (c), represents (with a greater reduction) Mr. Freeman's 20-inch sheet with one 20-inch scale.

Here we must first cross the diagram diagonally with section 1; then (first dropping to the bottom) with section 2, and again with the first part (3 a) of section 3, but we must now return to the left by the horizontal dotted line, and

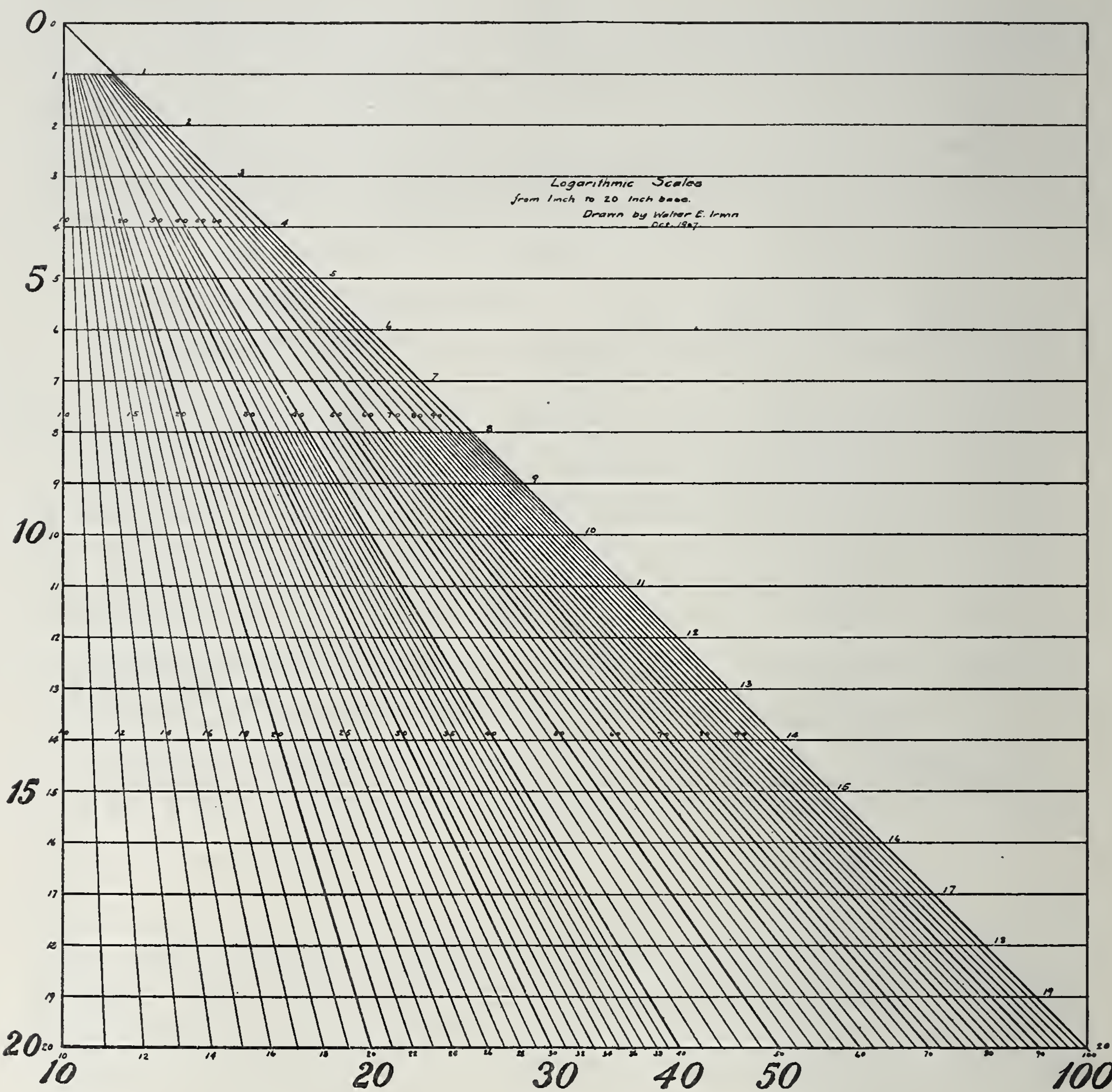


Fig. 5.

then again cross the diagram diagonally three times, as before: namely, with the remainder (3 b) of section 3, and with sections 4 and 5.

Figs. 4a and 4b show the practicability of using different scales for abscissas and for ordinates, in logarithmic plotting, when "cross-section" paper is used, as here proposed. This distortion of scales is of advantage in dealing with equations involving powers either much greater or much less than 1. In the case chosen, we have selected $\sqrt{x}$, $\sqrt[3]{x}$, and $x^{0.3}$. In such cases, the vertical or the horizontal scale is apt to run through a greater number of decades than the other.

On the square diagram, Fig. 4 (a), where the vertical and horizontal scales are equal, these give diagrams rather closely approaching the horizontal, and the approach would, of course, be still closer for still lower powers. This increases the liability to error in estimating the exponent by means of measurement of the ordinates and abscissas.

In the right-hand figure, Fig. 4 (b), the vertical scale is made twice the horizontal scale, and the three diagrams form better angles with the horizontal. Here

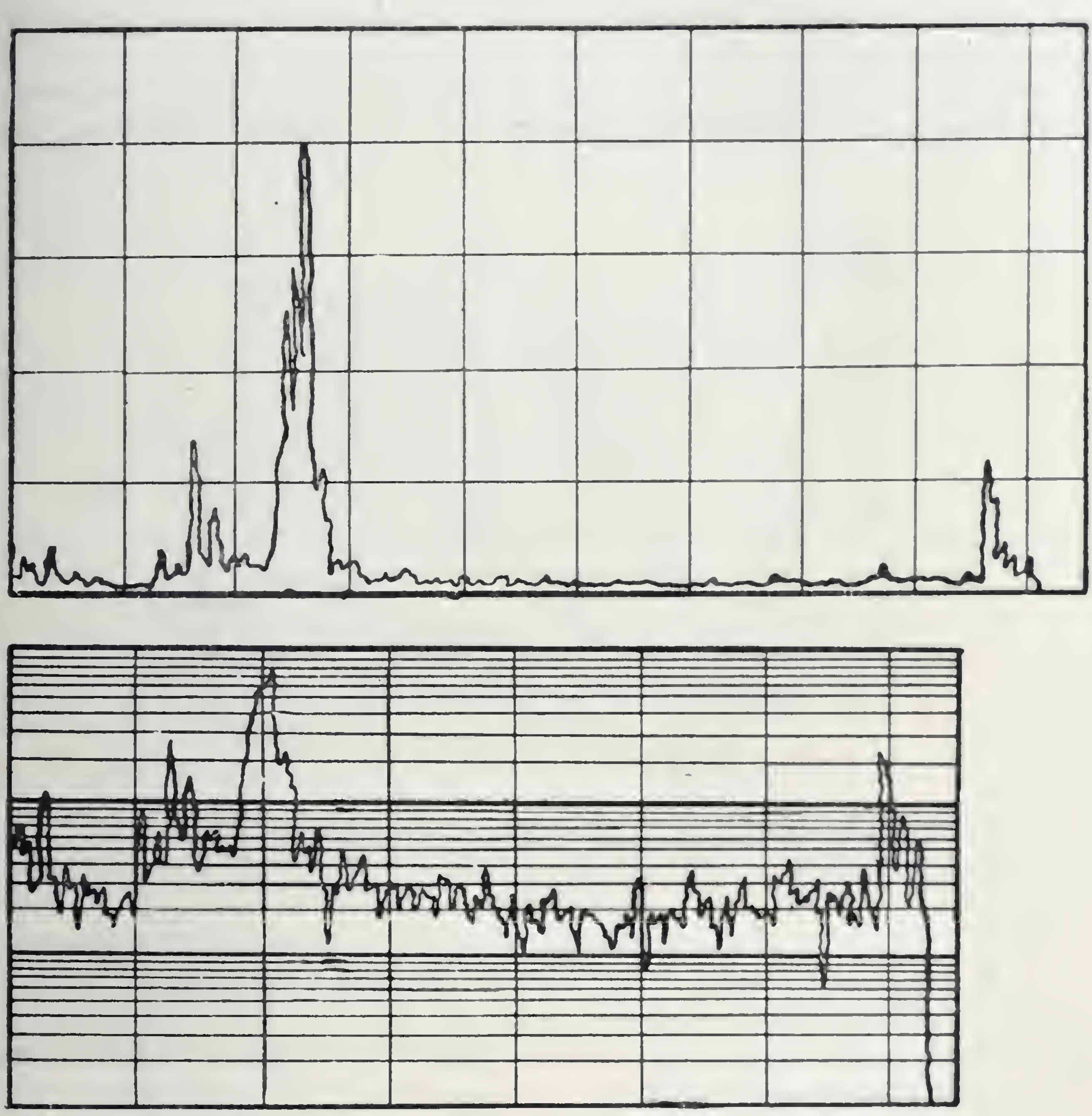


Fig. 6.

also, as in Fig. 1 (a), we must, of course, have different vertical and horizontal "Hess scales."

Fig. 5 shows a very simple device giving an infinite series of logarithmic scales, up to 20 inches, for use in plotting upon unruled drawing or tracing paper or cloth.

The figures on the left represent inches on the actual sheet, and each horizontal line gives a logarithmic scale; but of course any intermediate scale may

easily be obtained by drawing additional horizontal lines, at the corresponding elevations, upon the chart shown in this figure.

These scales are especially convenient in plotting with the horizontal and vertical scales different, as indicated in Fig. 4 (b).

Our late member, Col. W. H. Bixby, Corps of Engineers, U. S. Army, devised a graphical computing table, "after the method of Leon Lalanne."

Colonel Bixby used this chart as a conversion table. He used two logarithmic charts, the lines of one forming angles of 45 degrees with those of the other, and, in performing the conversions intended, he passes from one of these series of lines to the other.

Although Colonel Bixby's two scales are equal, each of his lines of powers occupies the position of the next lower power on an ordinary logarithmic dia-

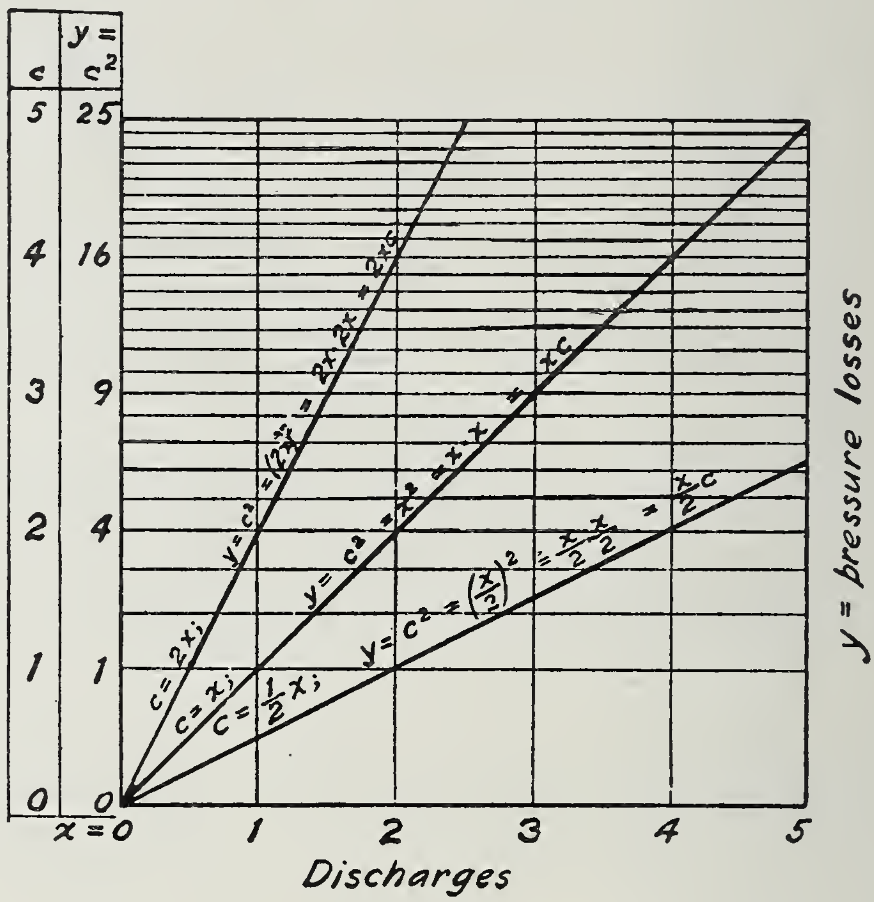


Fig. 7.

gram. Thus, his line of squares occupies the position of the line of first powers in an ordinary logarithmic diagram.

Fig. 6 illustrates a device suggested by Mr. George C. Whipple, for use in connection with the plotting of flows of torrential streams. (See "Engineering Record," Oct. 8, 1904, p. 434.)

When such flows are plotted on plain cross-section paper, the result is as indicated in the upper figure, where the large flows stand out as mountain peaks, while the low and ordinary flows appear almost as a desert plain near the axis of abscissas.

Mr. Whipple, while plotting the times or dates to a natural scale, as usual, uses a logarithmic scale for the flows, thereby exaggerating the small and mean flows relatively to the large flows. The former are thus shown more satisfactorily

than when the natural vertical scale is used; although no longer in their true relation to each other and to the large flows.

Fig. 7 represents a diagram used by the Hersey Manufacturing Company, of South Boston, Mass., for plotting the resistances of water meters corresponding to different discharges in gallons per minute. Here the discharges are plotted to a natural scale, while the resistances, which are supposed to be proportional to the squares of the discharges, are plotted to a vertical scale, in which the equal subdivisions correspond to the *square roots* of the pressure losses, and thus are represented by straight lines, instead of by curves, as they would be if plotted to natural scale. For convenience, the vertical scale is subdivided to correspond with the pressure losses or with the *squares* of the discharges.

Mr. C. J. Hopkins (Visitor).—The paper is instructive, but needs to be studied at length before it will be found to be useful.

The author discusses two general forms of equations, viz.:

for plain paper........................ $A = \pm y B \pm z$

for logarithmic* paper.................. $A = y B^{\pm x} \pm z$

using the former as a stepping-stone for the explanation of the latter. These equations appear to be at a disadvantage, since for:

plain paper y represents the right-hand intercept

and logarithmic paper y represents the left-hand intercept

making a comparison between the two confusing. If, however, we write these equations:

for plain paper........................ $A = \pm y B \pm z$

for logarithmic paper.................. $A = z B^{\pm y} \pm x$

then in both cases:

y represents the right-hand intercept

z represents the left-hand intercept

and x, which is contained only in the logarithmic equation, represents a quantity determined by a special process of maneuvering with a straight edge given in paragraph 72. The determination of this value x (or z as used and described in the paper for logarithmic ruling) is the most novel feature.

Since the object of the paper is to facilitate the discovery of an equation to represent plotted data, it would seem that a further change in the symbols composing the equations would benefit matters. Let us write for:

Plain paper........................... $Y = \pm r X \pm l$

Logarithmic paper..................... $Y = lX^{\pm r} \pm m$

---

* In paragraph 31 it is stated that the equation

$$A = \pm y B^{\pm x}$$

"can be plotted on logarithmic paper as well as on plain when x = 1." This is not true, since

$$A = - y B^{\pm x}$$

cannot be plotted on logarithmic paper, any more than one can obtain a logarithm to represent a negative number.

Every one is familiar with Y as the ordinate and X the abscissa for any one point; there remains then only to learn that

r = right-hand intercept (of Secondary)
l = left-hand intercept (of Intermediate or Primary)
m = "maneuvering" process figure (or distance of Intermediate from Primary).

If these equations are likely to be of value to any one they can be written in a note-book, and if once understood will always be self-explanatory.

A concrete example for each form of paper, fig. P and fig .L, will assist in simplifying the explanation, from which it will be seen that the:

Primary is the line whose equation is required.

Intermediate is a straight line equidistant from Primary (found by maneuvering with a straight edge, and occurring only on logarithmic paper).

Secondary is a straight line through the lower left-hand corner parallel to a straight line (the latter being the Primary or its Intermediate).

If we remember that the scales can be extended as required in either direction, the signs will take care of themselves except with reference to "m"; even here, if the Primary is above its Intermediate, its Y must be greater than the corresponding Y for the latter, hence the difference "m" must be positive. Naturally a similar explanation applies to a negative "m," when the Primary is below the Intermediate.

COMPARISON OF TWO PAPERS.

Plain Paper.	*Logarithmic Paper.*
(1) For straight lines equation must not involve more than two constants.	Same.
(2) Right-hand scale has divisions of equal length, with + and — values.	Same right-hand scale as with plain paper, and therefore requires to be marked off, meaning extra work.
(3) Left-hand scale has division of equal length with + and — values.	Left-hand scale has divisions whose lengths vary logarithmically, hence more difficult to construct and check for accuracy. Scale values are always greater than 0.
(4) Easy to think and check trend of curve, which, as a rule, may be anticipated.	Not easy to think and check trend of curve.
(5) Useful for checking data.	Useful for plotting simple equations involving some power.

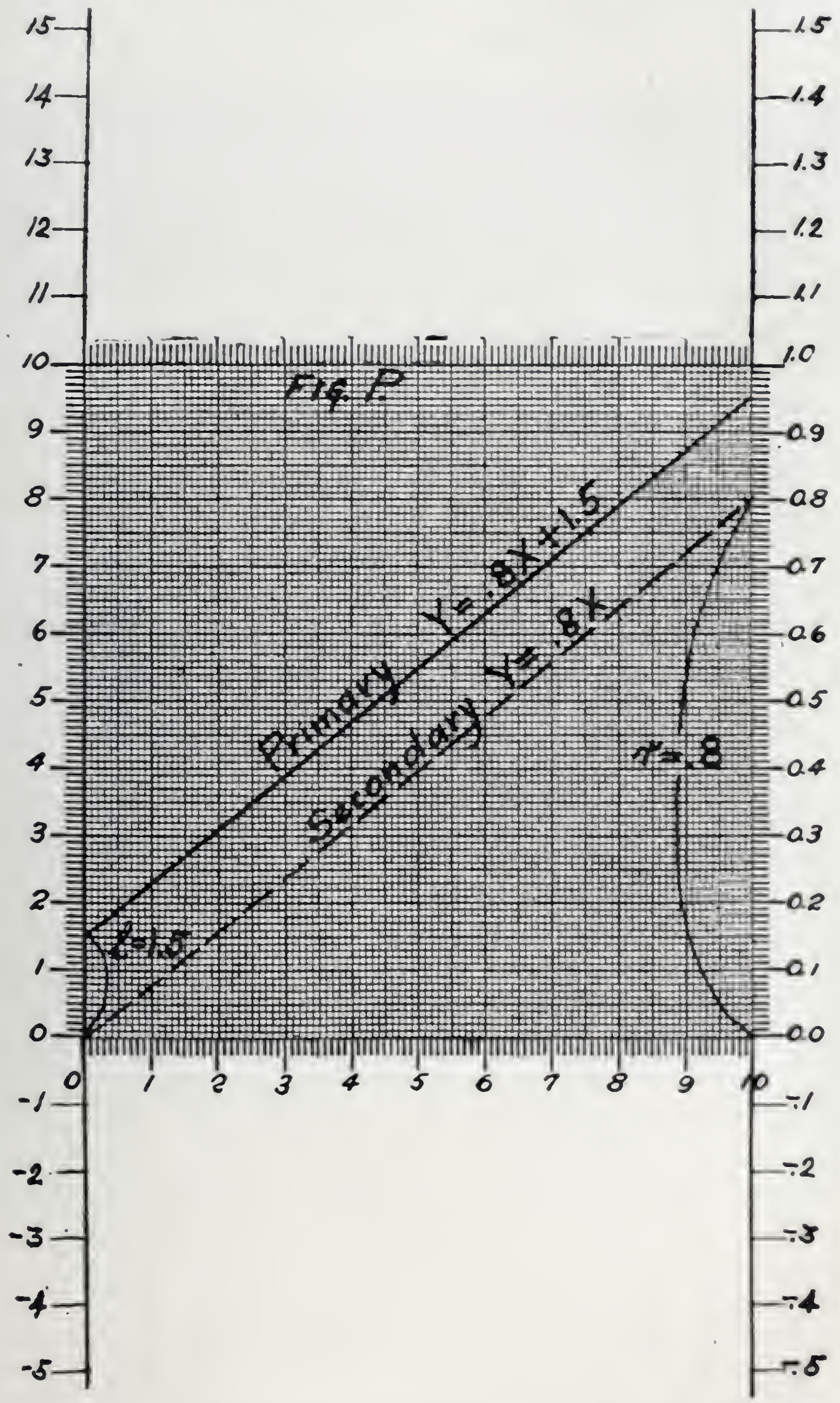
What would seem to be one disadvantage with logarithmic paper is that it possesses no zero. In dealing with observations, the zero point can generally be very accurately determined; for instance, suppose the rate of flow of water in a pipe is being measured as produced by different heads, it is quite definite that if there is no head, the rate of flow is zero, yet this point cannot be plotted on logarithmic paper.

In such case where the form of the equation is known, as merely involving some power which would be a curve on plain paper, the graph may often be readily obtained on logarithmic paper by determining the value of the right and left intercepts and drawing straight lines. An example will illustrate this fact: for

a simple pendulum, using the usual notation, we have for relation between time of oscillation and length of pendulum:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

or $T = 1.11\ L^{.5}$ (corresponding to the form $Y = 1X^r$)



First we draw our Secondary from lower left-hand corner to .5 (or center) on right-hand scale, and then above this through 1.11 on the left-hand scale we draw the Primary, a straight line parallel to the Secondary. This is a far simpler

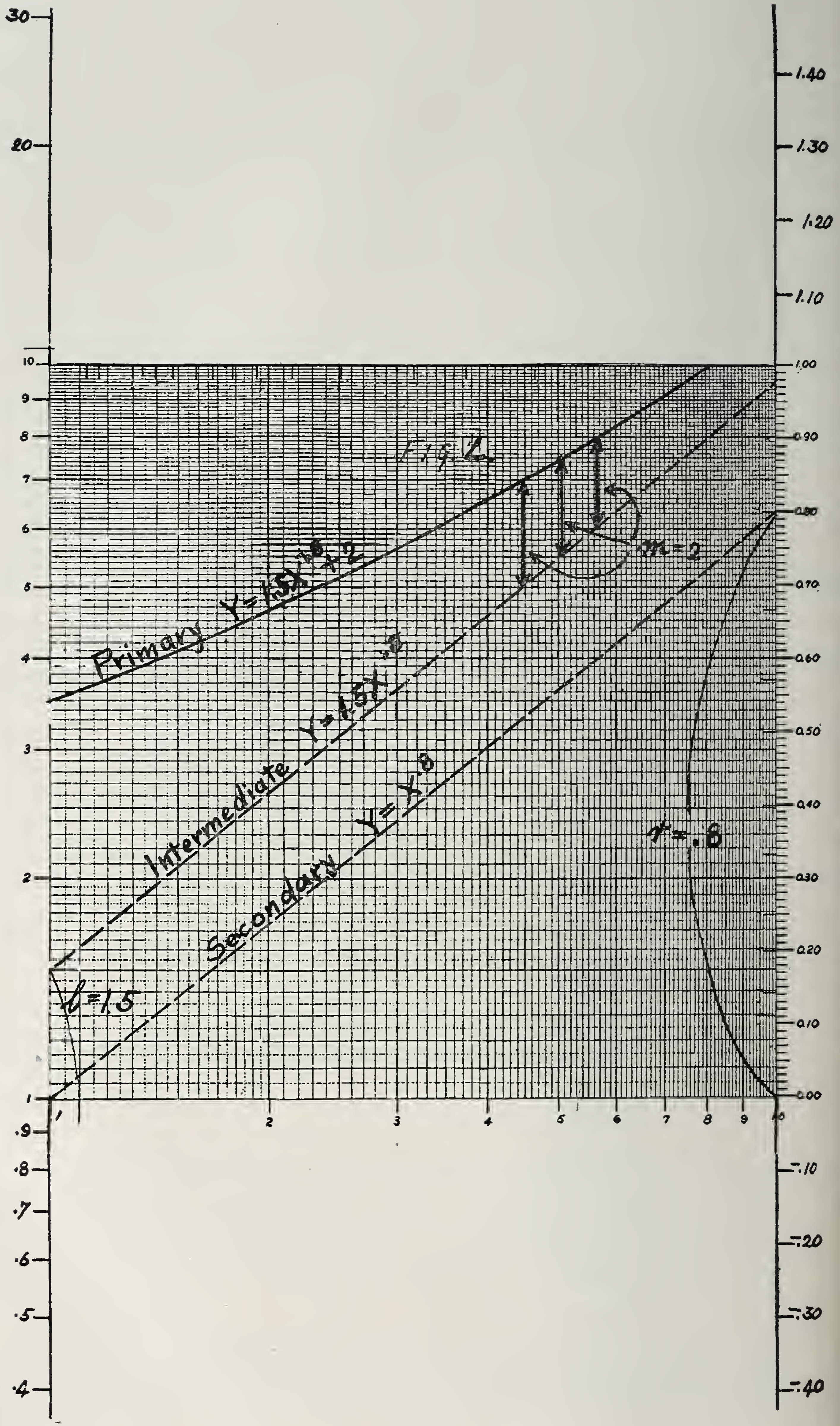


Fig. 2
Primary Y=1.5X^.8+2
Intermediate Y=1.5X^.8
Secondary Y=X^.8
l=1.5
m=2
r=.8
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-.10
-.20
-.30
-.40

process than using plain paper where several points would have to be calculated and the best possible curve drawn through these points by using approximately fitting curves.

Mr. Hess.—Any criticism concerning the inaccuracy in the sectioning of the figure on page 170 must apply equally to all of the plates or not at all; the figures were made on purchased sheets that were all printed from the same plate. As a matter of practical moment such inaccuracies as are apt to be found in such plates are not important. It is very rarely indeed that the data which are plotted on such paper do not in themselves contain inaccuracies that are larger by many times than the plate errors.

I believe that the paper is more convenient than the slide rule in many ways, though giving results which may also be obtained by the slide rule. Having a series of observed values, the exponent of each value can be found with the slide rule, as, necessarily also, can the exponents for all of the values.

Make a series of plotted observations. They will be responded to by some equation involving an exponent x, but no one curve can be drawn through all of the values, hence they cannot all be responded to by any one exponent x. An average exponent x will have to be fixed upon. The mathematician will, as a rule, from the general character of the observations be able to know what the exponent x should be; he may verify that conveniently by slide rule methods to his full satisfaction. The man who is not a mathematician will draw a line through the group of observation plottings. He may also draw two other curves enclosing the whole group and then say: My series of observations may be defined mathematically as lying in an area bounded by the equations of the upper and lower curves and averaged by the equation of the averaging curve. Using the upper curve as a maximum and the lower as a minimum will not permit going far wrong.

The real object of the suggested employment of the cross-section paper is to provide a convenient method for the non-mathematical analyst. To the average engineer data plotted as suggested will convey far more information of the relationship of the various quantities than will mere tabulated data. The plotted data will contain all that is essential; but they are bulky. Equations deduced as suggested occupy less space in a note-book. They may be, and probably will be, entirely empirical, but they will truly represent the observation—no more and no less. The mathematician will want more; he will want not empirical equations, but fundamental ones, involving the relationship of possibly far more factors than are contained in an empirical expression that would be satisfactory to the working engineer. The fact is that the engineer who deals with materials and such phenomena as come within his ken finds that these vary so widely that accuracies beyond those of the suggested methods are of no moment.

Paper No. 1054.

LONG-DISTANCE ELECTRIC TRANSMISSION OF POWER.

L. S. BRUNER.
(Junior Member.)

Read April 13, 1908, at meeting of Junior Section.

Long-distance electric transmission of power has developed simultaneously with the development of the turbine as a means of using water power for commercial purposes at points distant from the source of supply.

The development of water power on a large scale, and for use at other places than the source, has been of comparatively recent origin. In fact, most of the work has been done in the last twenty years. Water power has, of course, been in use for numbers of years, but with the advent of the modern turbine this form of energy was placed in a position where it could be economically developed and made to compete with that developed by means of fuel.

Other sources of energy, such as wind, solar radiation, and tidal energy, while they are interesting in an experimental way, are not at the present time on a commercial basis. This leaves us only the comparison of the relative merits of power developed by fuel and by water. It is easily seen, therefore, that where the price of coal (the principal fuel at present) is high, there the greatest demand for cheap water power will be. This is the case on the Pacific slope, where the price of coal is very high, and the water in such position that power may be developed economically and on a large scale.

Another section of the country that is making use of the available water-supply is New England. Here the supply is abundant, but the heads are small, while on the Pacific coast heads of several hundred feet are of common occurrence. This fact, of course, calls for a different type of turbine.

One other place where water power is developed on a large scale, and one that is perhaps better known, is the Niagara Falls district. Here are located the Niagara Falls Power Company and the Canadian Niagara Power Company, both transmitting power to Buffalo; the Electrical Development Company, transmitting power to various

points in Ontario, Canada, and the Ontario Power Company. The power from the Ontario Power Company is transmitted to Syracuse, N. Y., and various other points in New York, over the lines of the Niagara, Lockport and Ontario Power Company, which company buys the power from the Ontario Power Company at the international boundary-line.

It was soon seen that for the commercial development of water power there must be some economical way in which it could be carried to places where it was to be used, since it was obvious that on account of the inaccessibility of the location and distance from commercial and railroad centers of most water powers, the industries using the power could not be located near the power plant.

It was for this reason that electricity, as a means of transmitting the power, was made use of.

The turbine, revolving on either a horizontal or a vertical shaft, is generally connected directly to the electric generator, and, for long-distance transmission, alternating currents are used. From the generator the current is carried to the transformers, where it is transformed to a current with a very high voltage, and from here it goes to the transmission line. There are two ways of constructing the line, namely: overhead and underground. It is obvious, however, that to construct a line underground for a distance of say one hundred miles might take too large an amount of capital to put the undertaking on a paying basis. From the line it is taken to the substation, and after passing through step-down transformers used either directly in the form of an alternating current or by means of converters, it is changed to a direct current at the voltage desired, and used as such.

It is necessary to keep the cost low, and therefore requisite that the line wire should be as small as possible, on account of the cost of both the wire (or cable) and the structures supporting it. As the size of the cable varies with the square of the current to be transmitted, and again, since the power also depends on the product of the current and voltage, it is essential that the current should be small and the voltage high. Voltages as high as 60,000 and 75,000 are at present being used. The latter, however, in only a few cases. Since direct-current dynamos are not economically constructed to generate these high voltages, we make use of the alternating-current generator and transformer to get the required voltage. It is thus seen that at the present time the alternating current is the most advantageous means for the

long-distance transmission of power; the greatest disadvantage being the insulation.

In line construction two methods are in common use: namely, the two-phase, three-wire; and three-phase, three-wire; the latter being more common. In this method the cables are strung in the form of an equilateral triangle with the apex at the top.

The line is supported on either wooden poles or steel towers. If wooden poles are used, there are two ways in which they may be employed—either as single poles or as "A" frames. If "A" frames are used, the distance between supports can be double the span if single poles are used. The advantage in doing this is the saving in cost of insulators. The life of wooden poles is comparatively short, and it is on this account that steel towers are often used in line construction. In some cases the first cost of steel towers is even cheaper than the first cost of wooden poles, especially where the price of wood is high. This is so on account of the much greater distances at which the towers can be placed, the length of span being from three to five times as great as the span for poles.

The next step is the physical construction of the line wire. The materials used for this purpose are copper and aluminum. While copper has a higher conductivity, higher mechanical strength, and freedom from corrosion, aluminum has the advantage of lightness; thus reducing the weight to be carried by the supports. The conductivity of aluminum is about 63 per cent. that of copper. It must, therefore, have a sectional area 1.66 times as great as copper, for the same current. Then, again, the specific gravity of copper is 8.9 and of aluminum 2.7, so that the weight of the aluminum cable is approximately one-half the weight of a copper cable. This reduction in weight is a large item in the cost of the line. The material must have sufficient strength to support its own weight plus the stress due to wind and, in northern climates, the weight due to a coating of ice and consequent larger area exposed to the wind. This latter consideration is one of the disadvantages of aluminum on account of the increased sectional area.

The height of the line above the ground should not be less than thirty feet for such high voltages, although in some cases twenty-five feet has been used as a minimum. This is necessary on account of the electro-static charges that may be induced between the line and the ground.

The above will also determine the height of poles and towers after

having made due allowance for sag in the line. Insulators used in high-tension transmission are usually made of porcelain, as glass has not sufficient mechanical strength. Another important factor is the protection of the line from lightning; such as grounded wire, lightning arresters at the substation and generating plant, and line lightning arresters; few of which have proved entirely satisfactory.

Having considered the design of the line in its essential parts, the location would be the next consideration. The line should be as straight as possible in order to reduce the length. It is also well to have the line run along some natural or artificial boundary, which might be the boundary-line for farms, etc., along the line (township lines, etc.), as this makes it much easier to secure right-of-way. It is not necessary to have flat country; in fact, there are even some advantages in having hilly or at least rolling country, since the towers can then be placed on the tops of hills, or summits, and so reduce the height of towers for the same amount of clearance. Unlike telegraph and telephone lines, there is a considerable sag in the line on account of the increased mechanical strength of the cable, with a reduction in the initial tension caused by pulling the wires to a horizontal position. This amount will vary as the square of the distance, so that in hilly country the span can be increased by the method of placing towers on the summits and allowing the sag to follow the contour of the hollow, and for this reason profiles of the right-of-way are made.

The lines of the Niagara, Lockport, and Ontario Power Company will now be described. This company has for its object simply the transmission of power. As stated before, it buys its power from the Ontario Power Company at Niagara Falls.

The power-house of this company is located on the Canadian side of the Niagara River in the gorge below the Falls and directly opposite the American Falls. The advantage of this location is that the turbines and generators are on the same floor and are only a short distance away from each other, thus reducing the length of the shaft and power lost in torsion and friction. The power-house contains only the generating apparatus and accessories. An interesting point in the construction of the power-house is the design of the roof. Situated as the power-house is, in the gorge, trouble is likely to be experienced from large masses of ice and snow falling upon the roof. To overcome this the roof is built with heavy trusses in order to withstand this shock, and steam pipes are laid in the roofing in such a position

that any snow or ice resting on the roof may be melted by passing live steam through them. This method is also used for melting ice at the intake works, which are located on the Canadian side about a mile above the Falls. From the intake works the water is carried underground in steel pipes to the turbines. The turbines are arranged in a double row, there being two to each generator. The turbines are of the inward flow, double central discharge or balanced twin turbine, designed to deliver 12,000 H. P. under a 175-foot head. The generators have a capacity of 7500 Kw. each and deliver three-phase 25-cycle current at 12,000 volts and 187.5 R. P. M. The current is then taken to the step-up transformers, which are located in a building on the bluff directly above the power-house, and is here transformed to current at 62,500 volts. From the transformer house the power goes directly to the line which runs down the river about six miles. At this point the line crosses the river and the power is delivered to the Niagara, Lockport, and Ontario Power Company at the international boundary-line. The line then continues to Lockport, a distance of 16 miles, at which place is located a substation, and from this substation three lines branch out, one line going to Buffalo and vicinity. The other two lines supply Syracuse and various other points by means of branch lines.

Of the two main lines running to Syracuse, the first line was located almost entirely along the right-of-way of the West Shore Railroad. The supports for this line consist partly of triangular lap welded steel towers and partly of wooden "A" frames; the "A" frame line extending from Churchville (about thirty miles west of Rochester) to Syracuse. The spans where steel towers are used had a standard length of 550 feet, and where "A" frames were used a span of 220 feet, the sags being respectively 19 and 3 feet at 60° F. The other main line is on a private right-of-way throughout, and at no place is this less than 75 feet wide, while at some places it is 300 feet wide. From Mortimer (six miles south of Rochester) both lines are on a 100-foot right-of-way as far as Fairport, a distance of about 10 miles. At this point the "A" frame line returns to the West Shore Railroad. The line which is built on the private right-of-way is built with square galvanized iron towers. The standard span is 550 feet, but this is varied at places to fit the contour of the country.

The towers are of an interchangeable type with heights of 35 feet, 42, 49, 57, and 75 feet. They are designed to resist forces including

the weight of the cable with one-half inch ice covering and wind pressure of 15 pounds per square foot. The cable is 0.5 square inch area, 0.6 pound per foot weight, and made of stranded aluminum cable of 19 strands having an outside diameter of .925 inch. The longest span on this line was 1253 feet, with a sag of about 80 feet, where the line crosses a swamp and it was found impossible to build towers on this ground. For this span 75-foot towers were used, guyed in the direction of the line to secure extra strength against the unbalanced

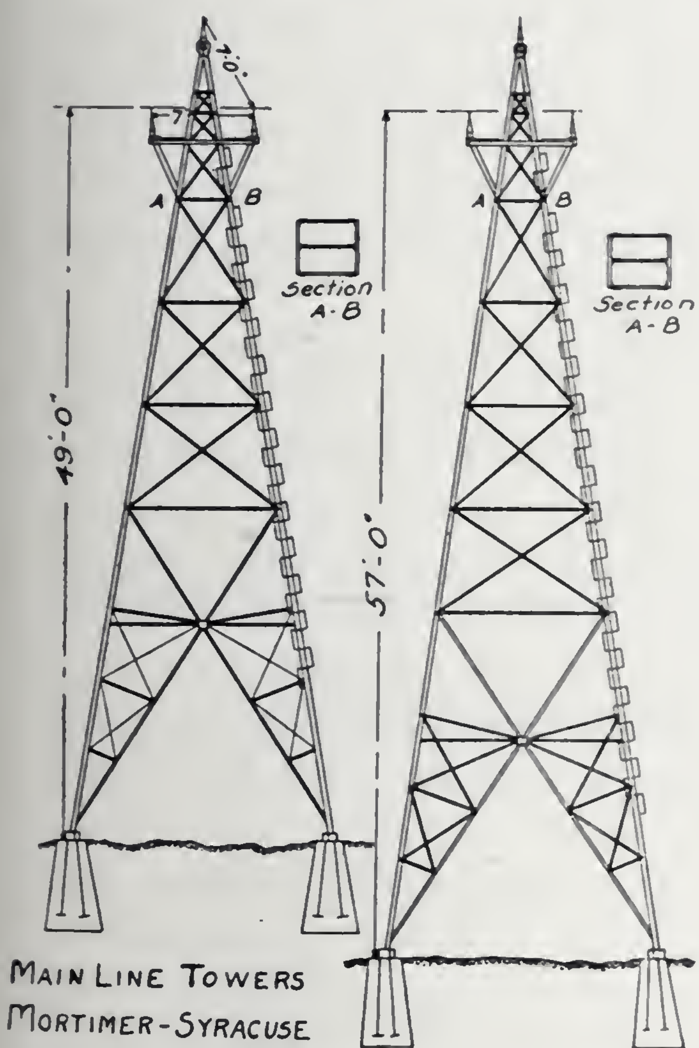


FIG. 1.

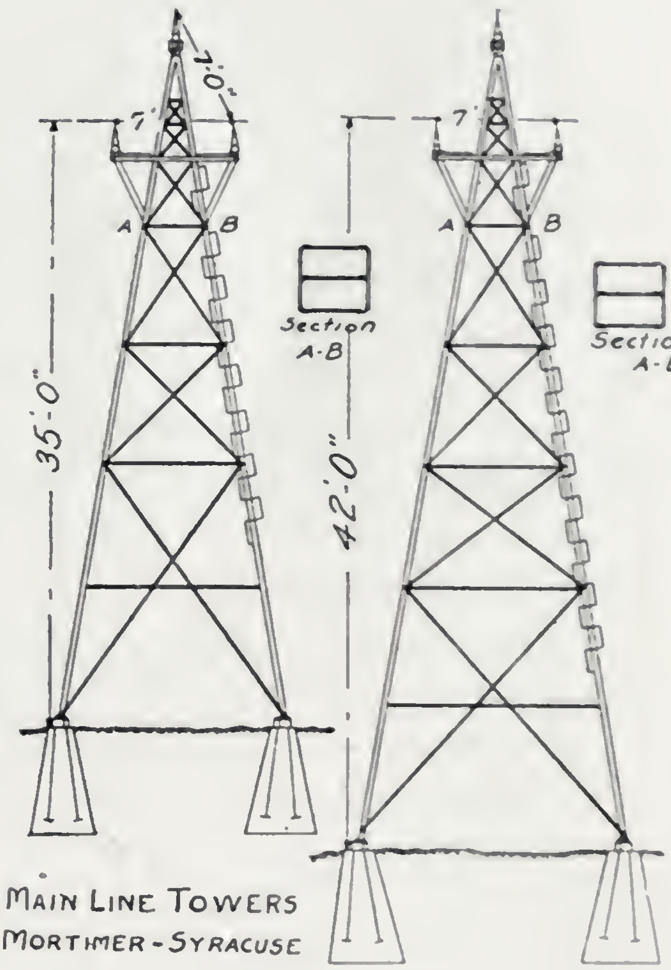


FIG. 2.

horizontal pull. Another case where a long span was used was where the line crossed the outlet from the Owasco Lake. This span was nearly 1200 feet long, crossing a deep valley. The towers at either end being located on hills, it was possible to use the standard 49-foot tower.

The standard foundations consisted of concrete reinforced with expanded metal, in which were embedded two rods firmly anchored by discs at the lower end. To these rods were bolted the legs of the

towers. In crossing the Montezuma swamp special foundations were necessary. In this case the mud was excavated until a soft marl was reached at a depth of 6 to 8 feet, and upon this was placed a corduroy foundation consisting of two layers, upon which were built the standard concrete foundations, which, with the weight of the back filling, took care of any up-lift as determined by actual test. This part of the work was done almost entirely during the winter months when the ground was frozen.

The insulators were made of porcelain consisting of three petticoats, the diameter of the lower petticoat being 14½ inches and the height of the insulator being 19 inches. They were placed at the vertices of an equilateral triangle seven feet on a side, and mounted on steel pins. A groove in the top of the insulators supported the cable which was tied to the insulator by means of ties in both directions, forming a loop on the top of the insulator.

Lightning arresters were located on the tower and pole lines. Their construction consisted of two horns deflecting away from each other at the top. These were grounded and spaced approximately 4400 feet apart, and also at either end of all spans of 700 feet or more. Lightning arresters were also installed at all branches being in series with the branch line. At these points 60,000 volt fuses and switches were also installed.

Branch lines were built with "A" frames of 220- and 280-foot spans, there being six branch lines running to Batavia, Rochester, Avon, Caledonia, Auburn, and Balwinsville.

In locating the tower lines the right-of-way was first staked out along the center line. As the center line of the towers was 25.83 feet south of the center line of the right of way, it was necessary first to set stakes along the center line of the right-of-way opposite the point at which the tower was to be located. After having set these stakes, three stakes were set in a line perpendicular to the center line at distances of 14.16, 25.83, and 37.50 feet from the first stake. These stakes were all centered and used for setting square templets for the concrete foundations. It is seen that those stakes which were set at 37.50 feet also located the south side of the right-of-way. The method used for locating the pole lines was simply setting a stake at the points at which the poles were located. At all angles and curves the spans were shortened and the tangents dead-ended by means of guys in the direction of the line. On all long tangents the tower

located at the middle point was guyed in both directions and towers were guyed at all points at which the spans were unbalanced, *i. e.*, where the span on one side was less than half the span on the other side. The general method of turning angles on tower lines was to place a tower 30 feet either side of the angle, guying it toward the angle, and a tower 150 feet from each of these towers guyed in both directions. On pole lines, poles were placed 10 feet from the angle guyed toward each other, and the first pole in both directions was guyed toward the angle.

TABLE No. 1.

Table of Curve Spans for Branch Lines.

(*Applying to A-frame structures. Standard Span 280 feet, Conductor No. 4, Stranded Copper.*)

The following table for curve spans applies to branch line construction under the following conditions:

(1) Tangents to be dead ended on each side of each curve.

(2) All spans of any curve to be of the same length.

(3) All curve spans of whatever length to be put up with a sag in accordance with curve for a 280-foot span.

Deflection Angle on Single Structure.	Length of Span Each Side of Structure.
.5 degrees	271
1.0 "	262
1.5 "	253
2.0 "	244
2.5 "	235
3.0 "	226
3.5 "	217
4.0 "	208
4.5 "	199
5.0 "	190
5.5 "	181
6.0 "	172
6.5 "	163
7.0 "	154
7.5 "	145
8.0 "	136
8.5 "	127
9.0 "	118
9.5 "	109
10.0 "	100

TABLE No. 2.

Table of Tower or Pole Spacing Adapted to Various Curves.

Degree of Curve.	Tower Lines, 550′ Spans.		Branch A-Frame Lines, 280′ Spans.		Main A-Frame Lines, 220′ Spans.	
	Dist.	Def.	Dist.	Def.	Dist.	Def.
0° 15′	408	1° 01′	247	0° 37′	200	0° 30′
0° 30′	380	1° 54′	225	1° 08′	183	0° 55′
0° 45′	355	2° 40′	208	0° 34′	172	1° 17′
1° 00′	332	3° 19′	193	1° 56′	162	1° 37′
1° 15′	313	3° 55′	179	2° 15′	153	1° 55′
1° 30′	296	4° 27′	166	2° 29′	144	2° 10′
1° 45′	282	4° 56′	155	2° 43′	136	2° 23′
2° 00′	....		145	2° 54′	128	2° 34′
2° 30′	....		130	3° 15′	116	2° 54′
3° 00′	....		117	3° 31′	106	3° 11′
3° 30′	....		107	3° 45′	97	3° 24′
4° 00′	....		98	3° 55′	89	3° 34′
4° 30′	....		90	4° 03′	83	3° 44′
5° 00′	....		85	4° 15′	78	3° 54′

For a given deflection, the above spans should not be exceeded by more than 10 per cent. nor lessened by more than 30 per cent. Special conditions require special consideration.

TABLE No. 3.

Table of Distances for Laying Out Dead Men.

Height of Pole.	Clearance.	Vertical Distance "A."	Horizontal Distance "B." 30°	45°
30	40 feet	28 feet	49 ft.	28 ft.
35	45 "	33 "	57 "	33 "
40	50 "	37 "	64 "	37 "
45	55 "	42 "	73 "	42 "
50	60 "	47 "	82 "	47 "
55	66 "	48 "	84 "	48 "

Distance "A" is from point of attachment of guy to pole, to surface of ground.
Distance "B" is from base of pole to point where anchor enters ground.
Distance from point where anchor enters ground to nearest side of trench is 9′ for 30° guy and 5′ for 45° guy.
All guys are to be placed at 30° unless local conditions make this impossible; in that case a suitable intermediate angle to be used; 45° is a maximum, not to be used unless absolutely necessary.

Special arrangements had to be used at railroad crossings, varying in different cases with the specifications of the railroad. The common method was to put in what was called a self-supporting span. This consisted of a steel tower guyed away from the railroad on either side of the track. In some cases self-supporting steel poles were used.

On the tower line the minimum clearance was 30 feet; the tower

heights were considered as the height of the top of the lower insulators above the ground. This permitted the use of 42-foot towers at angles in place of the standard 49-foot towers. On the standard spans of 550 feet with a 49-foot tower and 19-foot sag, a 30-foot clearance was obtained. At points where there were sharp rises in the ground it was sometimes possible to use 35-foot towers.

TABLE No. 4.

MAXIMUM ALLOWABLE DIFFERENCE IN ELEVATION OF TOWER TOPS ACCORDING TO LENGTH OF SPANS.

Aluminum Cables.		No. 4 Hard-drawn Copper.		Slack Spans (All Cables).		
Span.	Diff. Elev.	Span.	Diff. Elev.	Span.	Diff. Elev.	Sag.
150′	2	100′	4	25′	4	3
200′	4	125′	5	50′	7	4
250′	8	150′	6	75′	10	5
300′	14	175′	8	100′	14	7
350′	22	200′	9	125′	17	10
400′	30	225′	10	150′	20	12
450′	40	250′	11			
500′	50	275′	12			
550′	60	300′	13			
600′	70					
650′	80					
700′	90					

Substations were located at Mortimer and Syracuse, the substation at Mortimer taking care of two 20,000 H. P. incoming lines and five outgoing lines; the substation at Syracuse taking care of two 10,000 H. P. incoming lines and distributing the power to the various users.

These transmission lines were built according to the designs of Mr. R. D. Mershon, Chief Engineer of the Niagara, Lockport, and Ontario Power Company, by the Iroquois Construction Company, of which General F. V. Greene was President and F. B. H. Paine was Vice-President and Chief Engineer.

GEORGE VAUX CRESSON.

Died January 18, 1908.

George Vaux Cresson was born in Philadelphia, September 10, 1836, the son of William P. Cresson, a retired manufacturer and philanthropist, and of Susan Vaux. He had a Philadelphia ancestry extending back for eight generations.

He served his apprenticeship as machinist with Bement & Dougherty and established himself in 1859, the firm name being Cresson & Hubbard, at Twelfth and Noble Streets, as general machinists. Later, in 1866, they moved to the southeast corner of Eighteenth and Hamilton Streets, changing the firm name to Cresson, Hubbard & Smith. In 1867 George W. Hubbard retired and Mr. Cresson established in 1870 "The Philadelphia Shafting Works." He was probably the first manufacturer to take up the production of shafting and all its appurtenances as a specialty.

The development of this business was such that Mr. Cresson moved in 1888 to Allegheny Avenue west of Seventeenth Street, where a pattern shop, foundries, and large machine shops were built. In 1892 the firm was incorporated as the George V. Cresson Company, with George V. Cresson as president.

Mr. Cresson became a member of this Club on January 12, 1884, and served as a Director in 1892. He was a member of the Franklin Institute and served a term on its Board of Directors and was President of the Manufacturers' Club for three years. He was also interested in several other commercial and philanthropic organizations. His death occurred at his country residence, "Caversham House," near Elkins Park, Pa., January 18, 1908, surviving his wife but a short time.

Mr. Cresson was a man of untiring industry and ever zealous in the cause of justice and righteousness.

Henry J. Hartley,
James Christie.

LOUIS YOUNGLOVE SCHERMERHORN, C.E.

Died April 2, 1908.

Louis Younglove Schermerhorn was born in Greenwich, N. Y., November 18, 1840, being the fifth child of Barent Cornelius Schermerhorn and Catharine Witbeck. From a genealogy we learn that Barent Schermerhorn was the sixth in descent from Jacob Janse Schermerhorn, who arrived at Albany (then called Beverwick), N. Y., in the fall of 1636. On the ship's list of immigrants he is stated to have been fourteen years old. The family name is obviously Dutch and geographic in significance. The village of Schermerhorn is about fifteen miles north of Amsterdam. Upon a map dated 1604, a lake is indicated as DeScher Mer, and a point of land jutting into the lake is referred to as DeHooren. This lake was drained two hundred and fifty years ago, and the site is now cultivated land. The word Scher is cognate with the English word "sheer" meaning "clear" or "pure." The family name would mean, therefore, the "cape in the clear lake."

As the families of the early Schermerhorn's were of considerable size, it is probable that the original immigrant had numerous relatives, and that some who did not emigrate took active part in the stirring events that unrolled themselves in the Low Countries during the latter half of the seventeenth century, when William of Orange was holding by sheer force of personal magnetism a coalition of progressive communities against the reactionaries. It is not impossible that Schermerhorns fought at Namur and Neerwinden, and possibly on the banks of the Boyne. The Colonial records show that the first immigrant took an active part in colonial affairs, becoming a magistrate at Albany and also a mariner.

The descendants of Jacob Janse Schermerhorn continued to reside in the neighborhood of the Hudson River. The fourth in the line of succession, J. Cornelius Schermerhorn, was a landowner at Schodack Landing, N. Y., and an officer in the Revolutionary Army from 1775 to 1777. He was present at the surrender of Burgoyne. He also held civil office under the State of New York. His son, Cornelius, grandfather of our late member, was also a merchant and landowner and in military service, having been on the northern frontier as colonel of a regiment during the War of 1812. Barent Cornelius Schermerhorn,

father of Louis Younglove Schermerhorn, was commissioned as colonel on September 9, 1835, in the New York State militia. As might be expected from the nativity, these families were all more or less active as members of the Dutch Reformed Church.

Mr. Schermerhorn entered The Engineers' Club of Philadelphia in 1892 as an active member, and was well known for his continued interest and valuable services both in the business and scientific work of the Club. His excellent education and large engineering experience, combined with fluency of expression, fitted him to take a large part in the discussions at the meetings. The impress of his ability and earnestness is to be found distinctly marked upon our printed Proceedings. He was President of the Club in 1898.

Mr. Schermerhorn's preliminary education was acquired at Greenwich Academy, N. Y. His earliest intention in life was to study medicine. From 1860 to 1863 he studied civil engineering in the Rennselaer Polytechnic Institute, and subsequently took the regular engineering course at Union College, from which, in 1864, he received the degree of C. E. He was a member of the Sigma Phi Fraternity.

Very soon after graduation, he entered the service of the Saratoga and Hudson River Railroad Company, and rose to the position of Acting Division Engineer. During part of 1866 he was in the employ of the Toledo, Wabash and Western Railroad, but later in that year took charge of work in connection with Prospect Park, Brooklyn, N. Y., a position that he retained for several years. He related some years ago, to a member of the Club, how a mere accident was responsible for changing the current of his life for a long period. Crossing over to New York one afternoon, during his residence in Brooklyn, he decided to see the sights of Broadway from the top of one of the stages then running on that thoroughfare. His expedition was brought to a sudden close by a summer storm. From the shelter of a convenient doorway he noted the windows of the office of the firm that afterward employed him, and as soon as the storm abated stepped across to make a short visit. The firm was just considering a proposition to send an engineer to what was then the far west, Riverside, Ill. Mr. Schermerhorn did not wish to go, but as the firm urged that the engagement would be brief and the pay good, and that he could resume his position on completion of the western work, he consented. As a matter of fact, he stayed in the west sixteen years, in the course of which time, in 1874, he entered the service of the United States as Assistant Engineer at St. Paul, Minn. His return to the east was in consequence of being transferred

with Gen. Robert, from Oswego, N. Y., to Philadelphia. When, in 1890, Col. Raymond, Corps of Engineers, U. S. A., assumed charge of this district, Mr. Schermerhorn was retained as principal assistant.

His connection with the army had a perceptible influence upon him, so much so that he was thought by many to be a graduate of West Point. Association with line officers made him acquainted with many incidents of army life wholly outside of engineering experience. Some of those who were associated with him on the Board of Directors of the Club, will recall his account of the amusing incidents that attended the inspection of the district around Lewes, Delaware, as a location for fortifications. During his western service he was engaged in the following works of river and harbor improvement: Eagle Harbor, Mich.; Milwaukee Harbor, Annapee Harbor, Mich.; Harbor of Refuge at Grand Marais, Mich.

In 1891 he was appointed by the Secretary of War as a member of the Engineering Commission for Wilmington Harbor, Del., associated with Col. D. C. Houston and Col. C. W. Raymond. In July, 1891, he assumed the presidency of the American Dredging Company.

During the six years in Philadelphia in the employ of the Government, he carried into execution under Gen. Robert important work for the improvement of the Delaware River, and prepared the plan for the removal of Smith's and Windmill islands, together with a portion of Petty's island and adjacent shoals. This work was subsequently carried into effect by the American Dredging Company, as contractors, between 1893 and 1898, involving the removal of about twenty million cubic yards of material. The work was completed well within its estimated cost and nearly a year and a half in advance of the contract requirements.

In May, 1894, Mr. Schermerhorn was appointed by Mayor Stuart as a member of a commission having charge of the surveys for a projected ship canal between Philadelphia and New York.

In the fall of 1894 he was associated with Col. C. W. Raymond in the making of an examination and report to the city of Williamsport, Pa., upon a plan for protecting the city against floods in the Susquehanna River.

In 1901 he was elected Vice-President of the Philadelphia Maritime Exchange, an office that he held until 1903.

Mr. Schermerhorn married, in 1886, Romie Bovie Dods, who was descended from a French Protestant family. Of the four children, three are living.

Among Mr. Schermerhorn's contributions to engineering literature are the following:

Physical Characteristics of the North American Lakes. The American Journal of Science, April, 1887.

The Rise and Progress of River and Harbor Improvement in the United States. Journal Franklin Institute, April, 1895.

Report of Flood Protection for the City of Williamsport, September, 1895.

A Summary of the Rise and Development of Plans for the Improvement of Philadelphia Harbor. Proceedings, The Engineers' Club of Philadelphia, Volume XI (1894).

Breakwater Construction on the American Coast. Proceedings, The Engineers' Club of Philadelphia, Volume XIV (1897).

Modern High Explosives. Proceedings, The Engineers' Club of Philadelphia, Volume XV (1898).

A few phases in the Rise and Development of the Science of Mechanics. Proceedings, The Engineers' Club of Philadelphia, Volume XVI (1899).

The Water-Jet as an Aid to Engineering Construction. Proceedings, The Engineers' Club of Philadelphia, Volume XVII (1900).

The Panama Route (Contribution to a Topical Discussion on "American Isthmian Canals"). Proceedings, The Engineers' Club of Philadelphia, Volume XVIII (1901).

The Duty of the Engineer to his Contractors and Employees (Contribution to a Topical Discussion). Proceedings, The Engineers' Club of Philadelphia, Volume XVIII (1901).

Address before the National Rivers and Harbors Congress. Report of Proceedings of National Rivers and Harbors Congress, Baltimore, Md., 1901.

The Obstruction of the Navigation of Southern Rivers by the Growth of the Water-Hyacinth. Proceedings, The Engineers' Club of Philadelphia, Volume XX (1903).

Henry Leffmann,
Edwin F. Smith,
J. F. Hasskarl,
W. Copeland Furber,
Committee.

ABSTRACT OF MINUTES—CLUB.

Business Meeting, February 1, 1908.—President Spangler in the chair. One hundred and seventy-three members and visitors present. Minutes of previous meeting approved as printed.

The Secretary announced the death of Mr. George V. Cresson, Active Member, elected January 12, 1884, died January 18, 1908.

The report of the Tellers showed that Hugo Bilgram, C. D. Ehret, Carl Lieb, Alex Murrie, and J. Walter Ruddach were elected to Active Membership; that Howard K. Bunting, Thomas R. Henderson, William H. Pavitt, Jr., R. P. Perkins, and J. L. Watters, were elected to Junior Membership; and that Francis J. Drake was elected to Associate Membership.

Mr. Joseph W. Hunter, Active Member, read a paper on "Engineering Problems in Road Construction."

Col. Deming, of Harrisburg, extended the greetings of the Engineers' Society of Central Pennsylvania.

Business Meeting, February 15, 1908.—President Spangler in the chair. One hundred and fifty-six members and visitors present. Minutes of previous meeting approved as printed in the bulletin.

The Secretary read the communication from the Colorado Scientific Society of Denver, Colorado, congratulating The Engineers' Club of Philadelphia upon the successful opening of its new Club-house, and expressing its feeling of fellowship and good-will.

The report of the Tellers showed that Arthur Russell Cruse, Herbert Spencer Evans, Arthur H. Keen, George Washington Phillips, William H. Quigley, and Albert Mahlon Williams were elected to Active Membership; that Alwin F. Huch and Edwin Starr Young were elected to Junior Membership; and that Joshua Walter Cregar was elected to Associate Membership.

Mr. Theodore Kolischer called attention to the First International Congress of Refrigerating Industries, to be held in Paris, France, July, 1908.

Mr. W. L. Wilcox, Visitor, read a paper on "Recent Improvement of the Incandescent Lamp." The thanks of the Club were extended to him by vote.

Business Meeting, March 7, 1908.—President Spangler in the chair. Two hundred and forty-five members and visitors present. Minutes of previous meeting approved as printed in the bulletin.

The report of the Tellers showed that David Wilbur Horn and George Franklin Paving were elected to Active Membership; that Robert J. Colgan was elected to Junior Membership; and that William Shearer Evans was elected to Associate Membership.

The Secretary announced the death of Mr. William Seaton, Jr., Active Member, elected May 18, 1895, died January 18, 1908.

Mr. T. Kolischer, Active Member, outlined the work of the First International

Congress of the Refrigerating Industries, which is to be held in Paris, France, in July, 1908; and it was resolved that the Club be enrolled as a Donating Member of this Congress, and Mr. Kolischer was elected a delegate to represent the Club.

Mr. James Christie read a memorial on the death of Dr. Coleman Sellers.

Mr. Howard W. DuBois, Active Member, presented a paper on "The Detection of Salting in Mine Examinations." Mr. DuBois also exhibited some motion pictures illustrating life in the Canadian northwest, and showed methods of hydraulic mining.

Mr. George R. Stearns, Director of the Department of Public Works, Active Member, and Mr. George R. Webster, Chief Engineer Bureau of Surveys, Active Member, presented data on "Sewage Disposal," illustrated by lantern slides, obtained while in Europe on a trip of investigation for the city of Philadelphia.

Business Meeting, March 21, 1908.—President Spangler in the chair. One hundred and fifty members and visitors present. Minutes of previous meeting approved as printed in the bulletin.

The attention of members was called to the provisions of Article 9, Section 1, of the By-Laws.

The plan adopted by the Board of Directors for the redemption of Club bonds was read and announcement made of the election of Dr. Henry Leffmann, E. F. Smith, and Edgar Marburg by the Board of Directors as Trustees of the Bond Redemption Fund.

The Secretary announced the death of Mr. Jawood Lukens, Active Member, elected January 14, 1888, died March 10, 1908.

Mr. Grafton Greenough, Active Member, presented a paper on "The Mallet Type of Locomotive."

Business Meeting, April 4, 1908.—President Spangler in the chair. One hundred and seventy-five members and visitors present. Minutes of previous meeting approved as printed in the bulletin.

The Secretary announced the death of Mr. Louis Y. Schermerhorn, Past President, elected Active Member January 16, 1892, died April 2, 1908; Director 1896–97, President 1898, and Vice-President 1900–01.

The following amendments to the By-Laws, proposed by the Membership Committee, Wm. Easby, Jr., Chairman, H. P. Cochrane, and J. O. Clarke, and the original text of the articles were read:

Article 1, Section 3.—(Add) "Should he not have the required professional qualifications for Active Membership on reaching the age of twenty-seven years, he shall be transferred to the grade of Associate Membership."

Article 1, Section 5.—(Add) "An Associate Member may be transferred to the grade of Active Member by the Board of Directors when he shall have attained the necessary professional qualifications."

An abstract of House Bill No. 10,457, "For Acquiring National Forests in the Southern Appalachian and White Mountains," was read, and on motion it was unanimously resolved that, in the opinion of the Club, the interests of the country demand the passage of the bill. The Secretary was instructed to transmit a copy of the resolution to the Hon. Charles F. Scott, Committee on Agriculture.

Mr. John C. Trautwine, Jr., Active Member, presented a paper on "Socialism as Exhibited in Club Papers."

The report of the Tellers showed that Walter Davis Banes, Charles Elcock, James Edwin Gibson, and Frederic Hamilton Hill were elected to Active Membership; that Carl Peter Birkinbine, Henry Edgar Birkinbine, and Alben Warren Way were elected to Junior Membership; and that Robert Taber Eaton and Thomas Stewart Genay were elected to Associate Membership.

Mr. George Maurice Heller, Visitor, presented a paper on "The Design of the Centering for the 233-foot Span Concrete Arch of the Walnut Lane Bridge, Philadelphia." The paper was illustrated by lantern slides and was followed by a short discussion. The thanks of the Club were extended to Mr. Heller.

Business Meeting, April 18, 1908.—President Spangler in the chair. Eighty-one members and visitors present. Minutes of previous meeting approved as printed in the bulletin.

The President appointed the following a committee to prepare a memoir of Mr. L. Y. Schermerhorn: Henry Leffmann, Edwin F. Smith, J. F. Hasskarl, and Wm. Copeland Furber.

Mr. Henry Hess, Active Member, presented a dissertation on the CO_2 Engine, and followed it with a paper on "A New Development in Cross-section Paper."

The report of the Tellers showed that Rud. H. Klauder, Albert Lee Magilton, John Francis Murray, William Woods Pinkerton, and Nathaniel Welshir Sample, Jr., were elected to Active Membership; that John Gibson Hendrie and Thomas Ernest Rodman were elected to Junior Membership; and that Joseph Harvey Borton, Edward Jessup Hasse, Jerome H. Louchheim, and Walter N. Wolcott were elected to Associate Membership.

ABSTRACT OF MINUTES—BOARD OF DIRECTORS.

Regular Meeting, February 15, 1908.—President Spangler, Vice-President Dallett, Directors Christie, Clarke, Dodge, Develin, Head, Hess, Perrot, Quimby, and Twining, and Secretary present.

The President appointed the following Committees:

To formulate rules for government of house, and revision of by-laws: W. P. Dallett, Geo. T. Gwilliam, W. S. Twining, Wm. Easby, Jr., and Henry Hess.

To prepare Memorial on the death of George V. Cresson: James Christie, H. J. Hartley, and John Birkinbine.

To arrange for organization of Junior Members: Henry H. Quimby, J. O. Clarke, Richard G. Develin, Francis Head, and Emile G. Perrot.

The House Committee reported having engaged Walter Fargerman as steward, and outlined changes in equipment and disposition of rooms that will be required before the restaurant can be opened.

The House Committee reported that the cost of the new house with alterations and equipment to date totals $69,998.00.

The House Committee and the Treasurer were authorized to obtain fire insurance on the personal property in the house.

It was decided that for the present smoking during meetings of the Club will be permitted in the rear of the ventilator.

The Finance Committee reported in abstract bills paid $6,272.86; and unpaid $288.70.

The Meetings Committee reported papers arranged for future meetings.

The Committee on Junior Section reported that the Junior Members will be invited to meet February 29th to discuss the question of organization.

A communication was received from the Engineers' Club of Baltimore relative to the publications of this Club. It was ordered that the Baltimore Club be placed on the free list for our publication.

A communication was received from the Civil Engineers' Club of Cleveland, suggesting the desirability of all the technical societies in the larger cities of this country and in Canada coming into closer touch by confidential exchange of the names of members dropped for non-payment of dues, and for the admission to membership of members of other societies without payment of the usual entrance fee. The Secretary was instructed to reply that this would be contrary to the By-Laws.

A communication was received from the Young Republican Club of Philadelphia, inviting this Club to send a representative to participate in the Inter-Club Tournament. The Secretary was instructed to acknowledge this communication and to post it on the bulletin-board.

A communication was received from the Colorado Scientific Society extending congratulations and best wishes, and suggesting an exchange of publications. It was ordered that they be placed on our exchange list.

The Treasurer reported for the month of January:

Balance December 31, 1907		$3568.50
January Receipts		2429.50
		$5998.00
January Disbursements		748.11
Balance January 31, 1908		$5249.12
Bond Account:		
Balance December 31, 1907	$2974.44	
January Receipts	8125.00	
	$11,099.44	
January Disbursements	2100.00	
Balance Bond Account, January 31, 1908		$8999.44
Total Cash Balance January 31, 1908		$14,248.56

On motion, the salaries of the Secretary and Treasurer were fixed at $420 per year, each.

Special Meeting, March 7, 1908.—President Spangler, Vice-Presidents Dallett, Devereux and Easby; Directors Dodge, Cochrane, Christie, Clarke, Develin, Hess, Quimby, Perrot, Loomis, and Ledoux, and Secretary and Treasurer present.

The Finance Committee reported a plan for the redemption of Club bonds. Action on the plan was deferred until the next meeting of the Board.

The Membership Committee suggested a change of the By-Laws relative to the requirements for Junior Membership in the Club. It was referred to the Chairman of the Membership Committee and the Chairman of the Rules Committee for report to the Board.

The House Committee asked authority from the Board to purchase desks for the office, which was granted.

An estimate of $35 for painting the office on the fourth floor was read. Bids for fitting up the office on the first floor and basement were read: Herbert E. Havens, $576; Stacy Reeves, $650. The lowest bid was accepted.

The matter of extending full house privileges to other technical clubs with whom we exchange house and library privileges, was discussed and left in the hands of the House Committee.

The Committee on Junior Meetings reported that 24 out of 54 Junior Members of the Club were present at the meeting held February 29th, and a call had been sent out for a meeting March 7, 1908, for the purpose of organization.

The Meetings Committee reported that the schedule of papers had been arranged up to the summer recess.

The President read a letter from Mr. James M. Dodge, President of the Link-Belt Company, suggesting that owners of bonds, if they so desire, be permitted to apply the amount of their bonds in payment of entrance fees and dues of new members to be nominated by them, subject to the Club's rules of procedure in the admission of new members. The question was referred to the Finance and Membership Committees for consideration and report.

Regular Meetings, March 21, 1908.—President Spangler, Vice-President Dallett; Directors Ledoux, Loomis, Dodge, Clarke, Quimby, Twining, Christie, and Hess, and Secretary and Treasurer present, and Director Head reported sick.

The resignation of A. G. Menocal was received and was accepted as of January 1, 1908.

The Secretary announced the death of Jawood Lukens, who was elected Active Member January 14, 1908, and died March 10, 1908. The President appointed John Birkinbine to prepare a memoir.

The Treasurer reported:

Balance January 31, 1908		$5249.12
February Receipts		1481.27
		$6730.39
February Disbursements		1212.60
Balance February 29, 1908		$5517.79
Bond Account:		
Balance January 31, 1908	$8999.44	
February Receipts	50.00	
	$9049.44	
February Disbursements	4261.93	
		$4787.51
Balance February 29, 1908		$10,305.30

Cancelled Insurance on Club-house, $35,000.00. Premium $640.00.
Present Insurance on Club-house, $35,000.00. Premium $594.00.

The Membership Committee proposed amendments to the By-Laws, Article 1, Section 3, and Article 1, Section 5, providing for the transfer of Junior Members to the Associate grade, and of Associate Members to the Active grade, and they were adopted by the Board and ordered presented to the Club for action.

It was ordered that Article 9, Section 1, of the By-Laws be called to the attention of the members at the regular meeting on March 21st, and also printed in full in the bulletin.

The use of the Club-house and the meeting-room of the house by other technical organizations was discussed and referred to the House Committee for consideration and report.

The committees on the bond redemption plan reported a scheme of provision for redeeming and retiring the bonds by creating a sinking fund to be constituted of the entrance fees of new members and one-half of the surplus yearly income, and determining by lot the order of selection for cancellation. The details were discussed and the plan adopted, and ordered printed in the next bulletin to the Club. Past Presidents Henry Leffmann, Edwin F. Smith, and Edgar Marburg were elected Trustees of the Bond Redemption Fund.

Regular Meeting, April 18, 1908.—President Spangler, Vice-Presidents Dallett and Easby, Directors Clarke, Cochrane, Dodge, Ledoux, Perrot, Quimby, and Twining, and the Treasurer present. Mr. Clarke acted as secretary pro tem.

The letters of acceptance from the Trustees of the Bond Redemption Fund

were read. Dr. Leffmann, Chairman of the Board of Trustees, was in attendance and discussed the details.

Letters from Mr. Hugo L. Hund, Active Member, and the Pittsburg Chamber of Commerce, requesting that the Club take some action in the matter of the conservation of the natural resources of the country, were read, and it was decided that the matter should be laid before the next meeting of the Club.

The President presented a statement of the finances of the Club, and Mr. Christie reported an estimate of the cost of operation.

The Treasurer reported for the month of March:

Balance February 29, 1908		$5517.79
March Receipts		1708.51
		$7226.30
March Disbursements		4440.76
Balance Club Account		$2776.54
Bond Account:		
Balance February 29, 1908	$4787.51	
March Receipts	200.00	
		$4987.51
Balance March 31, 1908		$7764.05

It was resolved that no purchases be made for the Club, except provisions for the restaurant, or labor, without an order on the regular form signed by the Secretary, or in his absence by an officer of the Club; the duplicate to be kept on file in the Secretary's office.

It was ordered that public accountants be employed to assist the auditors in an examination of the accounts of the Club.

The Publication Committee was instructed to take charge of all the publications of the Club and informed that it is the sense of the Board that the Committee has full power to edit all papers before they are printed.

On the question of the sale of cuts belonging to the Club, the sense of the Board was that there is no objection to lending cuts to authors of papers for the preparation of duplicates, but they should not be sold, as they may be needed in making reprints.

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1908

President

H. W. SPANGLER

Vice-Presidents

Term Expires 1909
W. P. DALLETT

Term Expires 1910
WASHINGTON DEVEREUX

Term Expires 1911
WM. EASBY, JR.

Secretary
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THE ENGINEERS' CLUB

OF PHILADELPHIA.

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PAPER NO. 1055.

THE CONSTRUCTION OF THE EAST MARKET STREET SUBWAY, PHILADELPHIA, PA.

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(Active Member.)

Read May 2, 1908.

THIS paper is intended to deal especially with the methods of construction employed on the East Market Street Subway and sewers, and only incidentally with the design.

The subway structure is built for double track throughout its entire length, and has five stations: at Second, Fifth, Eighth, Eleventh, and Thirteenth Streets.

The two tracks are separated by a wall from the portal to Letitia Street, and westward of that point by a line of columns practically subdividing the subway into two longitudinal compartments. Four places occur on the line where the roof has been built in a single span, the center columns having been omitted. At these points it is intended to lay crossovers from one track to the other for the purpose of switching cars.

The stations at Eighth and Eleventh Streets are provided with overpassages, or bridges, giving access to both the east-bound and west-bound platforms from either side of the street. The station at Thirteenth Street is provided with an underpassage, leading from the

local platform level of the City Hall section to both the east-bound and west-bound platforms of the East Market Street road.

The entire length of the section is 5,888 ft. The general width of the subway structure is about 37 ft. out to out of walls, and the clear headroom is 14 ft. The distance center to center of tracks is 13 ft. 3 ins.

The width of the stations is variable; those at Eighth, Eleventh, and Thirteenth Streets occupying generally the entire width between the house lines of Market Street, while at Fifth Street the sewers on either side of the street occupy the space between foundation walls of the houses and the back of the station walls, and at Second Street the general width of the station is somewhat less than the width of the street. The length of the station platforms at Second, Fifth, Eighth and Eleventh Streets is uniformly 350 feet, and at Thirteenth Street 364 feet. Station entrances are provided either on the sidewalk or through the adjacent buildings.

The sewers follow generally a line distant 25 ft. from the center of Market Street on both sides of the subway, and at the stations either pass below the platforms, as at Second Street, Eighth Street, Eleventh Street and Thirteenth Street, or, as at Fifth Street, are deflected so as to pass between the foundation walls on either side of the street and the outside of the station walls. Both sewers are of variable shape and area of cross-section. They are 7 ft. by 7 ft. at Front Street, and gradually reduce toward the western end of the drainage area, the north side sewer terminating in a section of rectangular shape, 4 ft. by 3 ft. 6½ ins., and the south side sewer terminating in a junction chamber, which gathers the flow from City Hall and South Juniper Street. At Sixth Street on the south sewer, a junction chamber is built to receive a future low level sewer.

Intercepting chambers are built in both the main sewers at Letitia Street, and are connected by a cast-iron pipe sewer at right angles to the axis of the main sewers, with each other, and with a 3 ft. diameter sewer paralleling the north sewer to a point near Delaware Avenue, where it joins a sewer which discharges at the pier head line in the Delaware River.

The subway structure is built of reinforced concrete generally, and the stations of reinforced concrete and structural steel. The sewers are built of reinforced concrete, except where cast-iron pipe has been substituted in a few places.

The material penetrated has been principally sand, gravel, and

clay, with pockets of running sand occasionally, and with comparatively little water.

General Statement.

The problem of building a subway, flanked by two sewers, one on each side, occupying the entire width of the roadway, and at the stations, which cover 30 per cent. of the length of the line, occupying the entire width of the street between the houses, as on east Market Street, presents unusual difficulties. In the heart of the business district, and with the heaviest street-car, wagon, and pedestrian traffic in the city, the problem assumes quite big proportions. The maintenance in service of the telephone, telegraph, light and power services, gas, water-supply, and high pressure fire service, has rendered the problem still more difficult than would appear to the casual observer. This is so, also, of the old sewers on Market Street and the intersecting streets—all of which were found to be in a badly dilapidated condition.

Excavation.

The specifications provided that the entire work of construction should be done under cover of a wooden deck to be placed at the level of the original surface of the street, so as to disturb the traffic conditions as little as possible, and also not to cut off means of ingress and egress to the properties abutting on the work. It was found to be of considerable advantage in the way of expediting the work, to remove the excavated materials to a depth of 16 ft. below the surface in open cut, after which the cut was decked over, and the material removed from below this depth through hatch holes, either previously prepared or cut in the deck for the purpose. The width of the trench varied, as will be shown later, but the length of the cut operated on at one time was about 32 ft. for convenience of handling.

Prior to beginning the work, and also during the early stages, various methods of making the excavation were considered. After a very careful consideration of all of the conditions involved, it early became apparent that only the most primitive methods were applicable, and the pick and shovel method was adopted. The timbering which was a necessary part of the work, as well as the underground structures, prevented the use of the ordinary excavating machinery, although the writer had in mind and sketched during the early part of the work, a machine which he thought could be used to advantage. In fact, it was quite similar to a cut which has since appeared in an

engineering publication, of a machine operating a revolving cutting knife on the end of a boom, which can be swung in a circle, or raised and lowered like the boom of an ordinary steam shovel. A machine of this type, not too large, might have been operated to advantage on this work below the level of the underground structures.

The earth having been excavated is shovelled into half-yard dumping buckets and hoisted to the surface, where it is loaded into drop-bottom wagons for removal to the dumps.

A stiff leg derrick with a 35 ft. boom, provided with a bull wheel and mounted on a movable carriage, with a house inclosing the operating machinery, is used on this work. The maximum capacity of the machine as rigged is about 125 cubic yards per ten hours, but the average capacity of the machine, due to having to work between underground structures, is about one-half of this. The machinery consists of a double drum hoist, with an independent swinging gear provided with foot power and electric brakes, and operated by a 25 H. P. motor. Direct current is used at 550 volts. Sixteen such derricks were used in handling the excavated materials on the East Market Street Subway. The last two machines built were of far better proportion of mast height to length of boom, and thus of increased stability, were provided with 16 in. sheaves, were better built throughout, and occupied considerably less room on the street than the earlier built machines. Each machine has handled in the neighborhood of 25,000 cubic yards.

Timbering.

Due to different underground conditions, different methods of handling the work had to be used from block to block. Sometimes the same method was not used throughout the entire length of one block. The system of timbering must, of course, be changed to meet the subsurface conditions, and also to accord with the method of construction adopted for the particular place. The entire work could be comprised under the head of one or the other of the following systems:

1st. Building each of the sewers separately, and following this, the entire cross-section of the subway at one operation;

2d. Building the subway wall and sewer on one side of the street, and the sewer only on the other; the remaining wall and the roof of the subway in a subsequent operation;

3d. Building both the subway wall and sewer on each side of the street; the roof in a subsequent operation.

All of these systems were, of course, modified to some extent, where houses had to be underpinned. The second system, so called, was used on by far the largest portion of the standard subway.

The timbering at the stations, as a rule, required special handling so as to place it clear not only of the underground structures but also of the structural steel work as far as possible.

FIG. 1.—METHOD OF SHORING AND TIMBERING AT PORTAL.

All of the timber used for shoring and bracing, excepting that used as stringers under the rails, was "Short Leaf" Virginia and North Carolina Pine.

Systems of timbering are usually designed to follow what is known as "good practice," rather than to accord with the theories of earth pressure.

The sizes of the timbers were adapted to the material of the excavation, and also the weight of the buildings on the banks, as well

as to the width and depth of the ditch. Consequently where buildings were high and heavy, heavy timbering was resorted to.

The sizes were first determined theoretically for certain assumed

Fig. 2.—Trench Timbering West of Thirteenth Street.

conditions, and afterwards so modified as to accord with best practice in this line of work. Of course, the wales or rangers might each of them have been of different dimensions, with the heaviest at the bottom of the trench, to strictly accord with theory; but considerations other

than theories of earth pressure required in this case the larger timbers at the top of the trench. A recent writer on this subject has even proposed a theory which requires the heavier timbers at the top of the trench, and gives as one of the reasons for his theory that the bottom of the ditch will often stand for a considerable time without any bracing whatsoever. While the writer cannot subscribe to this newly advanced theory, he is convinced that there is very little justification for the application of the older theories to the design of systems of trench timbering. The best systems of timbering are provided to prevent a slip of the banks, rather than to hold up the banks after they have slipped, in which case only can the pressures approximate the theoretical pressures.

The upper two sets of timbers were usually made considerably heavier than would be required by the pressures. On the upper set was laid the deck, and additional width had to be provided for breaking joints in the planking. On the second set was usually supported all of the underground structures, such as water and gas pipes, electric conduits, etc. Both of these sets were made solid; *i. e.*, the braces were either in one piece or spliced to make them act as one piece. All of the other sets below the level of the second were provided with what is locally known as false rangers. By means of this system it is possible to lift out a short length of brace to allow the construction to proceed without cutting out a brace reaching from side to side of the ditch, thereby preserving the integrity of the timbering as a whole. Each of the cross-braces was secured in place with wooden wedges, driven from both sides simultaneously, following a timber which had been previously jacked into place with a screw jack, to maintain the distance between the rangers.

The cross-braces were generally placed 8 ft. apart along the longitudinal axis of the subway, and about 5 ft. apart vertically. The distances between the timbers in both planes were frequently changed to clear obstructions as they were encountered.

Where both walls of the subway were built before the core was removed from between them, the distance between the braces on the longitudinal axis of the subway was about 12 ft. This distance could possibly have been increased to some extent had not the refill been made back of the subway walls on both sides, the material frequently being piled up a considerable distance above the top of the walls and sloped back, forming practically two surcharged walls.

Of interest among the special cases mentioned is that of supporting

the banks at Front Street above Market Street, where the subway leaves the bed of Market Street. The excavation was made in the usual way excepting that it was all open cut, and the banks were sustained by raker braces, placed as the excavation proceeded. The maximum cut was about 30 ft.; the banks were heavy, and 60 ft. from the front face of the cut were some quite heavy buildings. In the bed of Front Street were a sewer, gas and water distribution pipes,

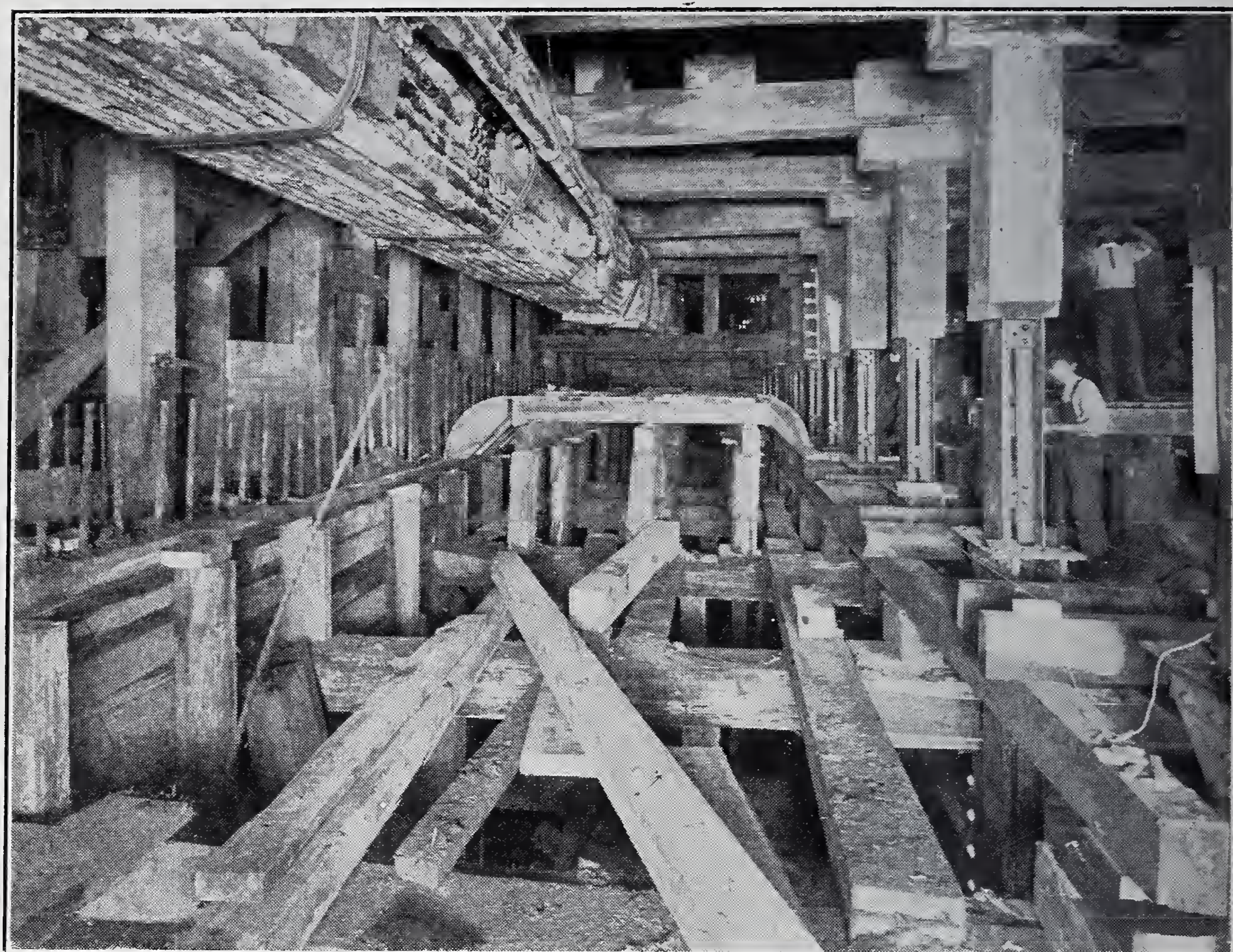


FIG. 3.—STANDARD SUBWAY. SHOWING ROOF FORMS IN PLACE AND METHOD OF TEMPORARILY UTILIZING CENTER COLUMNS OF SUBWAY TO SUPPORT SURFACE TRACKS.

and electrical conduits, among which were the long distance Bell and others of equal importance, all of which were kept in undisturbed service throughout the entire work. The removal of the raker braces as the work was built up under them, was quite a delicate matter, and had to be preceded in every case by the placing of others so as not to disturb the banks.

At the street intersections for expeditious working, the length of the trench was reduced, and generally the depth excavated in open

cut was about 8 ft.; after which it was decked over and the balance of the excavated material removed under the deck. It was also found in the operation of the derricks, that considerable advantage was gained by working them in pairs; a derrick taking out the top lift being followed closely by another taking out all the material below that level.

All of the excavation along the sides was made in the above manner,

FIG. 4.—STANDARD SUBWAY. SHOWING ROOF PARTIALLY COMPLETED AND FORMS IN PLACE.

but when the core was to be removed a different method had to be resorted to. It was invariably our practice to attack the core from one side of the street by driving a heading or drift into the bank, and enlarging that heading by working both ways from it. The headings were usually of about 8 ft. depth, which depth was maintained when the cut was lengthened. The excavation was then proceeded with in a vertical plane in lifts of from 4 to 6 ft., until subgrade was reached.

Supporting the Surface Tracks.—In advance of the excavation of

the side trenches the granite block paving was removed, and the street was opened alongside of and between the rails, and 12 in. by 14 in. stringers of long leaf yellow pine were inserted under each rail below the ties. The spaces between the ties were then filled solid with

Fig. 5.—First Lift Removed in the Core.

planking, and a layer of 2 in. plank spiked on the ties parallel with the rails, to bring them up to the proper level, after which the granite block paving was replaced on a bed of sand.

Needling for Track Support.—Following the construction of the side

walls, and before the roof was built, it was necessary to place the needles to carry the two surface tracks across the excavation, prior to the removal of whatever timbers might have been in the way of the

Fig. 6.—Approach to Portal. Roof Forms in Place.

roof. For this purpose 8 in. by 10 in. posts were erected on the side walls at the level of the base of the arch, and two 12 in. by 12 in. by 16 ft. timbers were thrown across the excavation, resting on the posts erected on the side walls and on a corbel set over a small post

on each of the center columns, at an elevation above the top of the roof. These needle beams were lashed together with 3 in. by 10 in. planks to prevent any lateral movement, the weight of the street being depended on to hold them down.

Several variations of this method were used where occasion required it; notably at the crossovers, where the center columns were omitted in the subway structure, and the roof put in in one span from wall to wall. At the first of these crossovers built on the line, viz.,

Fig. 7.—Standard Crossover. Method of Carrying Surface Tracks.

that west of Second Street Station, the finished roof was only a little below the street surface, and the problem presented was to carry the street surface with its two lines of tracks across the subway at a place where no permanent intermediate support, as in the standard subway, was available, and where the head-room below the street surface was insufficient for a truss to span the entire width of the structure. It should be said in passing that the surface conditions did not allow of the placing of a bridge truss between the tracks, otherwise they might have been suspended from above.

The method used was as follows: An intermediate support was made by using a small latticed steel column, supported at an elevation of about one inch above the finished underside of the roof slab on a 12 in. by 12 in. post to the subway floor below, and on this post, and on the posts erected on the side walls, the needles were supported in the usual manner. The latticing on the columns was arranged so as not to interfere with the placing of the reinforcing rods in either direction, and the columns were concreted in the roof. In due time

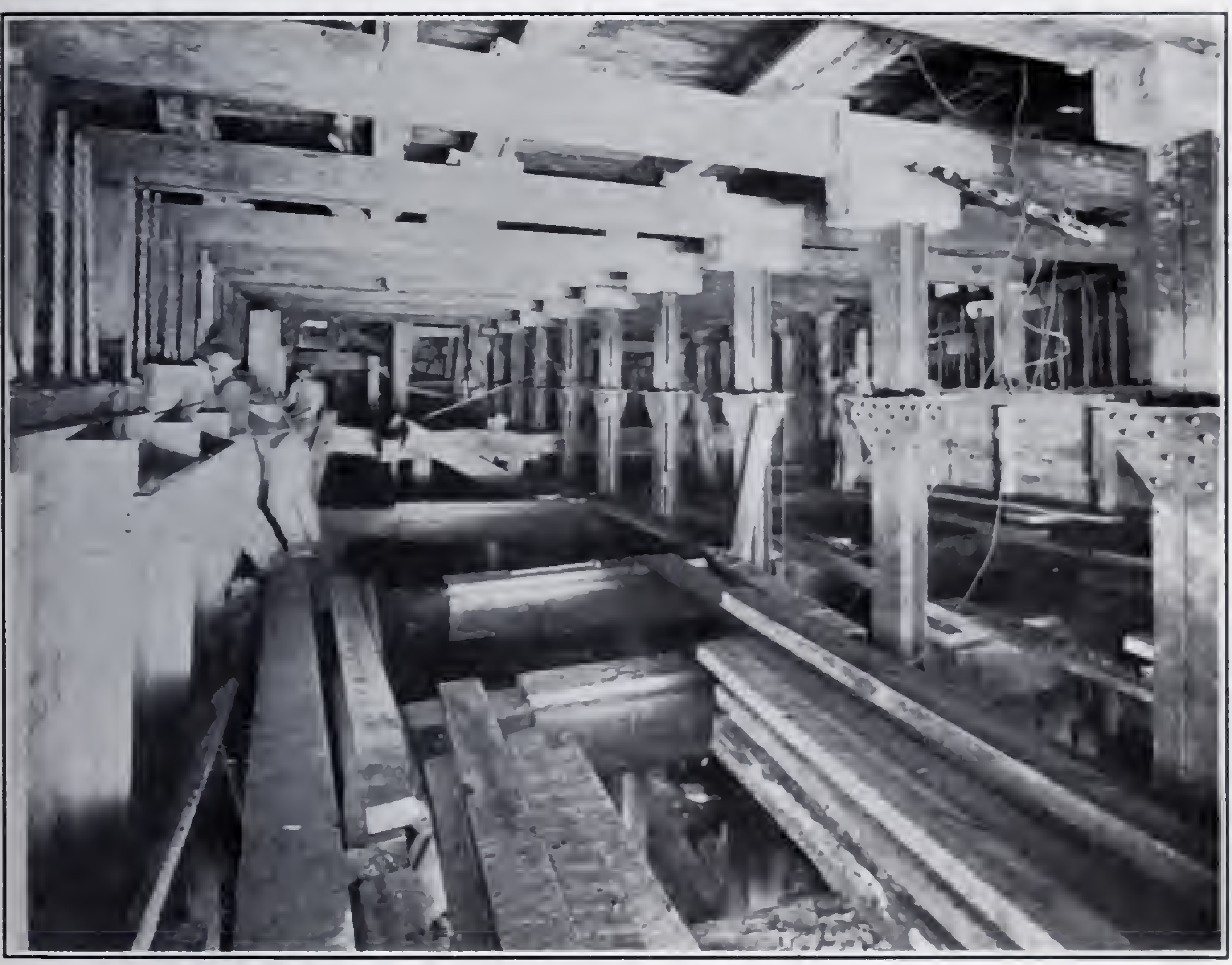


Fig. 8.—Standard Subway. Method of Carrying Surface Tracks.

the wooden posts, which were set up on wedges, were lowered and then removed, and the underside of this column, which had been raised above the forms, and which had been previously wrapped with close woven wire mesh, was plastered flush with the finished surface of the roof. This method of handling the problem worked so well, and was so simple and comparatively inexpensive, that it was used on two other of the crossovers, despite the fact that at both these places there was sufficient room above the finished roof for a truss to carry the street surface.

One other variation of the method of needling may be of interest. Between Letitia Street and Front Street, where the subway begins to rise to the surface, there was not sufficient room under the decking to conveniently place the concrete, the reinforcement, or the waterproofing. Accordingly, the rails were jacked up on the 12 in. by 14 in. stringers under them, sufficiently high to place 12 in. by 12 in. needles between the stringers and the rails; after which these needle beams were supported on the center and side walls of the subway on small lattice columns, as described under the timbering for the crossover, and the stringers were removed and these columns were concreted in the roof. These needles were placed 5 ft. apart along the axis of the subway, and the rails themselves were allowed to carry the traffic over this span.

Sheeting.—With several minor exceptions all of the sheeting or sheet piling used on this work was of rough 2 in. by 8 in. planks, 12, 14 and 16 ft. in length, and was hand driven. At street intersections, and at the ends of side ditches, the bulkhead usually consisted of short lengths of sheeting, set in place as the excavation proceeded. This sheeting, which was in from 4 to 6 ft. lengths, could not be driven, owing to the underground structures.

Decking.—The decking consisted of two courses of planking; the upper course of 3 in. by 9 in., which was laid close, and the lower course of 4 in. by 10 in., which was laid with 8 in. spaces between the planks. The lower course, which was laid parallel to the axis of the subway, was spiked to the upper cross-braces in the ditch with 80d wire spikes, and the upper course was laid at right angles to the lower course. The decking supported all the wagon traffic on the street without any difficulty whatever, and sustained unusually heavy concentrated loads at times.

Work at Stations.

The method of operation at the stations varied considerably from that of the subway proper, due primarily to the underpinning of the houses at these places, and also to the fact of their occupying practically the entire width of the street.

At Second Street the station wall is about 9 ft. from the house line, and the deepest excavation is, at least, 20 ft. below the bottom of the average foundation at this point. The buildings were all four and five story stores and light manufacturing buildings and warehouses, and were quite old, although none of them were extraordinarily heavy.

At Fifth Street Station the excavation occupied the entire width between the houses, and all of the houses were underpinned, the foundations being carried down to the level of the bottom of the new sewers, which abutted immediately against the houses. All of the buildings were old and some of them quite heavy.

At Eighth Street Station the excavation occupied the entire width between the houses, and nearly all of them were underpinned. All of the buildings, except those adjacent to the southeast quarter of the station, were very heavy and were occupied by department stores.

Fig. 9.—Second Street Station.

At Eleventh Street the station occupied the entire width of the street, and all of the adjacent buildings were underpinned. Some of the buildings, like the new Bingham Hotel, were exceedingly heavy and the foundations were anything but ideal, because of the fact that they had been added to from time to time, and the original were quite old. Some light underpinning was done at the Snellenburg building, but the underpinning of the Market Street National Bank building and the Inquirer building was quite difficult because of the character of

the subsoil under these buildings, which was a tenacious blue clay, and also because of the extreme weight of the buildings.

At Thirteenth Street Station, the buildings adjacent to the northeast, northwest, and southeast quarters of the station were underpinned. The building at the southwest quarter, the Wanamaker building, was founded at a lower level than any of the adjacent subway work. The buildings that were underpinned presented no unusual difficulties.

FIG. 10—NEEDLING FOR UNDERPINNING AT BINGHAM HOUSE.

UNDERPINNING BUILDINGS ADJACENT TO THE SUBWAY.

At quite a number of places along the line of the work, particularly where the subway passes close to the foundation walls of the houses, it was necessary to underpin the foundation walls to prevent settlement or undermining of the buildings.

The underpinning as practised on this work may be divided into three distinct classes, based on the character of the foundations and the method of doing the work:

1st. Continuous underpinning without the aid of needles;
2d. Continuous underpinning using needle beams;
3d. Isolated pier underpinning using needle beams.

It was our practice to take down the excavation to the depth of the bottom of the foundations, together with the general excavation, before proceeding with the underpinning.

The first method was used where continuous foundations existed, and where the depth of the underpinning was not too great. It simply

Fig. 11.—Underpinning at Bingham House.

consisted in removing the soil from under the foundation walls in alternate sections, 6 to 8 ft. in length, the sides of the excavation being sheeted as the excavation proceeded; then building the masonry, usually concrete, up to a point from 24 to 30 ins. below the bottom of the original footings, or, where it is necessary to remove the original footing on account of its not being sound, up to the level of the sound masonry, and of filling in between the original work and the new work with brick masonry in cement mortar, and finally wedging up

hard with steel wedges against the old masonry. Each section is completed before a new one is started, and the arch action of the masonry is depended on to temporarily carry the building while the section of underpinning is being completed.

This method was used at Strawbridge & Clothier's building at Eighth and Market Streets with complete success and without causing the slightest apparent settlement.

Continuous Underpinning, Using Needle Beams.—Considerable work was done in the vicinity of Front Street using this method. The underpinning was from 25 to 30 ft. deep. The excavation was taken down to the bottom of the footing as usual. Crib holes were sunk inside and outside of the buildings. These holes were short-sheeted as the excavation was carried down, in sections of about 4 ft. The crib holes outside the building were usually carried down to the depth of the proposed foundation. Cribs of 12 in. by 12 in. timbers were built up to a level above the bottom of the footings, usually sufficiently high to allow working space above the cellar floors for cutting out holes for the needles in the foundation walls. Unless the buildings were heavy, the inside cribs were not carried down more than about 4 ft. below the cellar floors. These cribs were capped with heavy timbers, usually 12 in. by 12 in. and 12 in. by 14 in., between which were placed the jack screws. The cribs inside and outside the buildings were usually about 20 ft., center to center, and the requisite number of 20 in. steel I beams to carry the load, each about 24 ft. long, were placed on the crib caps through holes in the foundation walls, wedged up with steel wedges and with shingles, so as to take the weight of the buildings. After this the earth was excavated below the foundations between the inside and outside crib holes. Short sheeting, as above described, was placed as the excavation proceeded, and the cribs were braced one against the other, and also against the banks as the excavated material was removed.

In this kind of underpinning it is usual to place on top of the needle beams smaller I beams immediately under the walls to carry the walls between the needles. This was discovered to be an undue refinement and absolutely unnecessary, and was omitted in by far the greater part of the work. The omission of these secondary beams made it far easier for the brickmason to make the closure between the concrete in the new foundations and the old foundation walls, which were usually of rubble masonry.

Isolated Pier Underpinning.—A considerable portion of the underpinning on the work was of this character. The cribs inside and outside the buildings were employed as usual. I beams, spanning from crib to crib, were usually made to carry a saddle from which were suspended secondary I beams which carry the pier footing. After the weight was taken by the jack screws, the excavation was made below the pier bottom for the underpinning, or, where the piers are sufficiently large, they are sometimes pierced the same as solid walls,

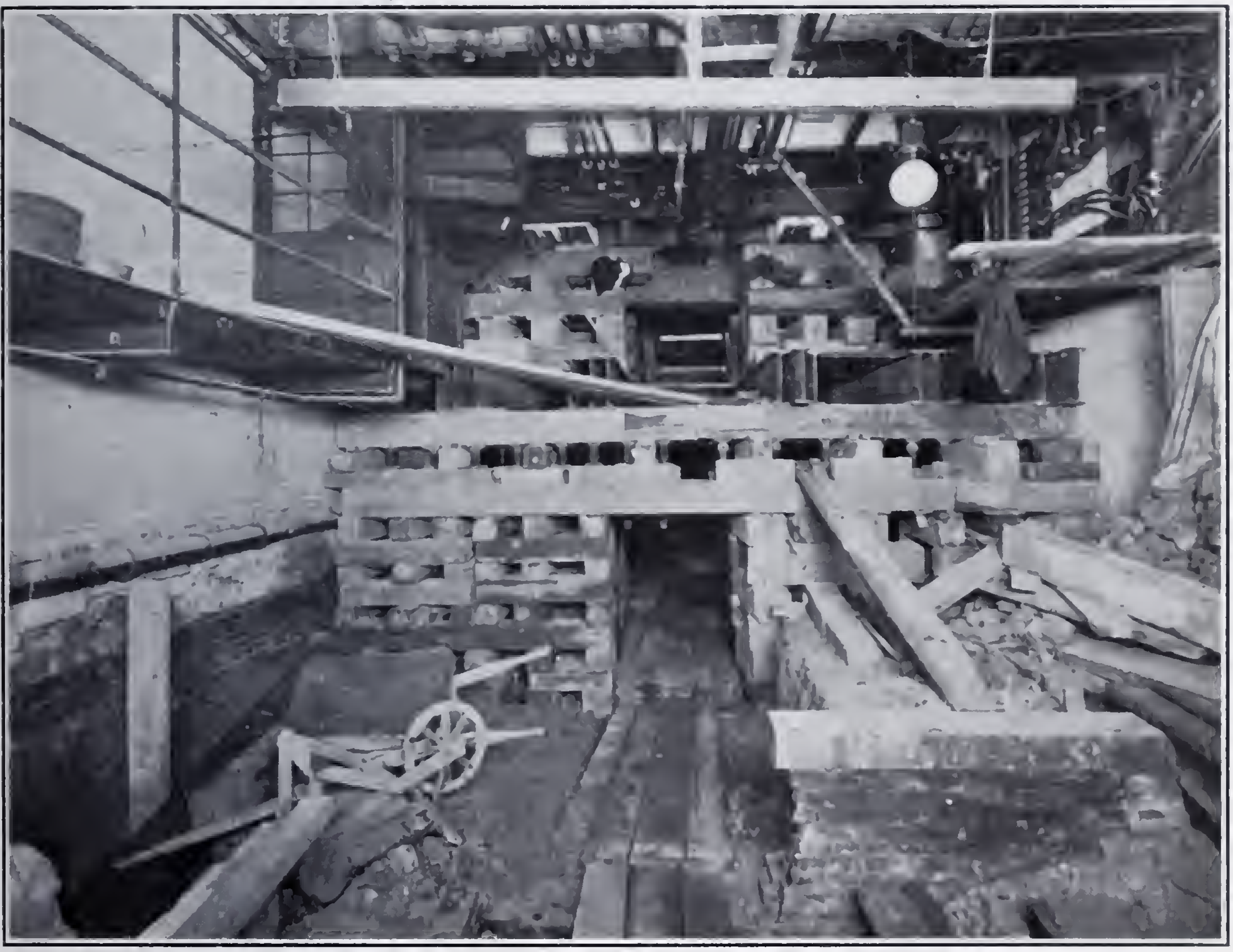


Fig. 12.—Underpinning at Inquirer Building.

for the passage of the I beams resting on jack timbers on the cribs, and the work conducted as with continuous underpinning. A good example of this character of work, where the pier was suspended, was the Sharpless building, of the Messrs. Gimbel Bros. establishment, in which an iron front nine stories in height is carried on one column and the party walls of the adjoining buildings. Another example is the Inquirer building, where two piers were underpinned by this method, the load on each pier being in the neighborhood of 200,000

lbs. This building was underpinned by the method of piercing the piers with needle beams. The Market Street front of Messrs. Lit Bros.' store consisted of a number of piers with curtain walls between them. As these walls carry no load whatever, no special precaution was taken to protect them. The piers, however, were underpinned, and in this case occurs a variation from the method of underpinning isolated piers herein described. The usual method of building cribs inside and outside the building, and of using needle beams placed on these cribs to carry the load, could not be used, as it was found impracticable to build cribs inside the building. Each individual pier was supported while the excavation was made under it, and the masonry placed, by means of what the underpinners call "spur braces" or spurs. This consists of a couple of raker braces placed against the pier to be underpinned, supported at the base on cribbing, and at the top of the braces carrying a head piece or cap, from which a sill is suspended by means of rods. On this sill piece, and in a seat provided between the raker braces, are supported several I beams cantilevering under the pier foundation, which is undermined one section at a time and underpinned.

On Market Street west of Front Street, the subway begins to curve into the private right-of-way of the Phila. Rapid Transit Co. The subway passes directly under the house at the northwest corner of Front and Market Streets. The north wall enters on the house line of Market Street at the party line between the corner property and the house west of Front Street, and emerges on the west house line of Front Street on the party line between the corner property and the first house north of the corner property; therefore, the whole west and south fronts of the building are supported on the subway roof. These two walls were needled in the usual way for continuous underpinning, the cribs and needles being so placed as to allow the building of the north and center walls of the subway in sections. When these sections were built the weight of the needles was transferred to a series of drums, as the underpinners call them,—vertical posts set up on jack screws,—the cribs were removed, and the several sections of subway walls connected. Permanent steel girders were built in the subway roof, for the purpose of carrying the future foundations of a heavy building to be erected at this point. The drums were arranged so as to allow the placing of these girders as far as possible without changing the temporary work. When these girders were in place the weight of the building was transferred to them and all the temporary work

was removed. The concrete roof of the subway was then built between these girders, and the masonry underpinning of the buildings was completed on top of the subway roof.

Sixty-five buildings were underpinned on this work with frontages varying from 20 ft. to 150 ft.

Concrete.

All of the concrete was mixed by machinery, in approximately half-yard batches. The revolving drum type of machine with loose paddles was used and gave entire satisfaction. Owing to the fact that, because of insufficient room, the machine could not be loaded with a derrick, as is usual where the mixer is elevated above the surface, some mechanical means was required to be provided for that purpose, which would not encroach too much on the street surface. Bucket elevators and belt conveyers have been used for this purpose in large concrete plants of more or less permanent nature, but the elevating device which was required on this work was one which could readily be dismantled and moved as the concrete mixer was moved along the line of the work. Two distinct types of elevating devices were developed, and, it is believed, first used on this work. That used in connection with the McKelvey machine was simply an elevating bucket of a capacity of a whole batch of loose material, which was raised and lowered in a wooden gallows frame provided for the purpose. The other device, used in connection with the Smith concrete machine, consisted of a bucket or a box which was attached to a steel frame, which worked on a hinge, and which lifted an entire batch of loose material from its position at street level through a whole quadrant to the funnel on the machine. The operating mechanism in both cases is a single drum hoist. The dumping buckets and boxes were measured up and marked so that the proportions for the different mixtures could be measured directly.

Each of the mixers was mounted on a carriage to facilitate handling from place to place, and each mixer was driven independently by a 10 H. P. electric motor mounted on the carriage.

Water was supplied the mixers from temporary connections made with the water distribution pipes on the street, and the concrete was made of that consistency which required an amount of water equal to about 16 per cent. of the quantity of mortar.

Under the discharge end of the machine was placed a sheet-iron

lined wooden trough, with an iron lifting gate, the box of a capacity of a whole batch of mixed concrete.

The concrete was deposited in the work through chutes in the deck, discharging either into the forms or on to platforms provided for the purpose. During the winter months each mixer outfit was augmented by a vertical steam boiler of 10 to 12 commercial H. P., for the purpose of heating the water, sand, and stone, and a two inch pipe with cross-arms of 1 in. pipe at right angles to it, pierced with $\frac{1}{8}$ in. holes, and connected with the boilers with a short length of steam hose, served to supply sufficient heat to prevent freezing by blowing live steam into the sand and stone. A permanent 1 in. connection was taken off the boilers and turned down into the water barrel which was mounted on a platform back of the concrete machine, and served to heat the water used in mixing the concrete. No precautions were taken to prevent freezing of the concrete, other than covering it with salt hay after it had been placed; and concrete was placed when the temperature at the street surface was as low as 15° Fahr. No bad effects of the freezing of the concrete are noticeable in the work constructed at low temperatures.

In addition to four half-yard mixers of the McKelvey type and three of the Smith make, there was provided a small portable Smith machine, driven by a gasoline engine, and mounted on a wagon body. One improvement of this machine over the larger machines of the same make used on the work, was that the mixer drum was dumped by simply depressing a lever, instead of by operating a screw which required considerably more time. This machine formed a valuable adjunct to the floating equipment, and was used wherever the quantity of concrete to be placed would not warrant the use of the larger machine. It was easily demonstrated that this was really the proper type of concrete mixer for use on such work as this, which required either constant shifting of mixing plant—which, by the way, was quite expensive—or wheeling of concrete quite long distances, which was not advisable for several reasons outside of its cost. The machine was easily drawn by a pair of horses, and was ready for instant operation, and could be placed on the surface in such a position with reference to the work as to either pour the concrete directly into the forms below or greatly reduce the length of wheel.

Three mixtures of concrete were used in the work:

1: 2: 4   1: $2\frac{1}{2}$: 5   1: 3: 6

The 1 : 2 : 4 concrete was used in all places where work was below the level of the permanent ground water, and in particularly thin sections. The 1 : 2½ : 5 mixture was used in all work pertaining to the subway proper; and the 1 : 3 : 6 mixture was used in the sewers and sewerage appurtenances.

The materials used in the aggregate may be mentioned in passing. Pebbles varying from ⅛ in. to 1 in. diameter, dredged from the bed of the Delaware River near Bordentown, N. J., and completely washed in the process of screening, were used as the concrete aggregate. They were beautifully graded, and formed a far denser concrete than is ordinarily to be had with broken stone. The point is mentioned because this is probably the first large piece of work in this vicinity in which gravel was used for this purpose. The sand used was principally a coarse, gray sand, well graded and washed, dredged in the Delaware River opposite Gloucester, N. J., and is locally known as "Gloucester Beach" sand. Several brands of cement were used, but by far the major portion of the work was built with "Vulcanite" cement.

The capacity of the concrete plant provided was far in excess of that required so far as the actual mixing was concerned, but it was found by experience that the most economical method of placing concrete on this work was one in which the length of wheel was not over 150 ft. Furthermore, on account of having to change timber as the work was built up, continuous work on the walls, etc., could not be provided. It was necessary, therefore, to temporarily suspend work at a given place from time to time. For this reason, if portable machines of sufficient capacity had been provided they could have been readily moved from place to place, and consequently fewer of them would have been required. Each machine has mixed upwards of 12,000 cubic yards of concrete. The capacity of the individual mixing machines used on this work was determined by the rapidity with which the concrete could be placed—about 75 cubic yards in ten hours is the maximum quantity ever handled by a concrete mixer on this work.

Reinforcing Rods.

As quite large quantities of reinforcing rods were to be used, and as many of them had to be bent to different radii, the question of a power machine for that purpose arose early in the work. No machine was available for bending the twisted rods which were used throughout

this work. Ordinary square or round bars could be bent on a tire bender, but the ordinary tire bender would not bend twisted rods; accordingly a machine had to be devised for the purpose.

Another feature of the bars used on the work determined to some extent the design of the machine; *i. e.*, the bars for use in the sewers had to be bent to varying radii, and have a piece of tangent at each end.

The general principle of the machine as built is that of the tire bender. Corrugated case-hardened rolls were used in place of plain ones, as in the ordinary tire bender. The adjustable roll was actuated by a hand wheel operating a rack and pinion determining the position of the roll and, therefore, the radius of curvature. By running this roll entirely out of the plane of the rods while the machine was in motion the rods were passed out of the machine without further bending, thus providing the proper tangent section on the end of the rods. The machine is geared so as to operate rapidly, and is heavily built, and is driven by a link belt by a $4\frac{1}{2}$ H. P. electric motor. The machine will bend any size of rods up to 1 in. square to any radius up to 9 ft. A graduated scale set on the rack indicates when the roll is in the proper position to bend any given radius.

It was not thought at the time that there would be sufficient cutting of rods to warrant the use of a power cutter, and therefore it was proposed that all of the rods that required cutting would be cut with a hand shear. There was, however, no hand shear on the market that was guaranteed to cut a 1 in. square twisted bar; but a machine without a name plate, evidently built in some small shop for its own use, was obtained and found to work admirably.

Concrete Forms.

The designing of forms for use on this work required that several distinct points be kept in view. They should be:

1st. Of as simple construction as possible to allow of rapid dismantling or collapsing;

2d. As compact units as possible to allow of handling under the street surface, and in cramped positions generally;

3d. As strong as possible to allow of constant re-using;

4th. As light as possible for facility of handling.

North Carolina pine, fairly free from sap, was used throughout, excepting in some instances where panelling was required, where white pine was used.

Both tongued and grooved and beveled edge stuff was used. The sheeting or lagging for the main walls and slab roof was 2 in. by 10 in. plank generally 16 ft. in length, tongued and grooved, and planed both sides. The necessity of accurately centering the tongue and groove where planks are planed both sides is obvious.

The following spacing of uprights was allowed with sheeting or lagging of different thicknesses:

Distance Between Supports.	Commercial Size of Sheeting or Lagging.
48 in. centers	2 in.
36 " "	1½ in.
30 " "	1 in.
18 " "	¾ in.

In designing the forms the concrete is assumed to weigh 150 lbs. per cu. ft., and the allowable unit stress in the timber used was taken at 1,000 lbs. per sq. in.

The forms used for encasing the center line columns in concrete were made of ⅞ in. stuff, properly battened. Three sides of this form were made the entire length of the column and hinged together, and the other side was placed as the form was filled with concrete. The fourth side was made in sections of about 3 ft. length, each section being held in position with loose battens, which were supported in notched pieces set on and protruding beyond the adjacent side. Wooden wedges were used between the loose battens and the sectional front boards of the form to hold them in position. The form itself was held in position in the following manner: The center line columns were built of structural shapes—generally four angles—and several tie plates, arranged so that the web was transverse to the center line of the subway. The forms were set around the steel column on a previously built plinth or base of concrete, and were held at a distance of 1½ in. from the steel on all sides by 40d nails driven through the form on the line of the web of the column, to hold the form from moving in the direction of the longitudinal axis of the subway, the moving of the form in the other direction being prevented by nails driven through the side leaves of the form and just touching the steel angles—the forms, of course, being of such dimensions as to provide the proper amount of concrete to envelop the steel. No bracing of any kind was required to hold these forms in position, other than the nails which acted to support them, and they were filled at one operation, the forms being removed after thirty hours. The column caps were

made of light lagging, each side being battened together and the four sides bolted, so as to admit of easy removal and re-erection.

Crude oil was used for greasing the forms to prevent adhesion of the concrete, and was found to be satisfactory.

The following rules were observed in removing roof forms, subject of course to variation due to the conditions of temperature and moisture, etc.:

Standard roof: leave forms in at least three weeks;
Load (street-car tracks) can be put on in five weeks.

Fig. 13.—Section of Station Platform. Showing Ducts, Center Column Forms, etc.

Crossover roof: Leave forms in at least five weeks;
Load (street-car tracks) can be put on in seven weeks.
Center posts in crossover can be removed at any time after centers are removed.

Station roof: Leave forms in at least one week;
Load (street-car tracks) can be put on in two weeks.

If it became necessary to load the structure before the expiration

of the required time, the forms were allowed to remain in place until that time had elapsed.

Supporting Surface Tracks on the Finished Roof.—Subsequent to placing the concrete roof, and while the needles are still in position, the water-proof layer is placed. The water-proofing consists of a sheet of asphaltic mastic and is placed in two layers, each one-half inch in thickness, considerable care being exercised to see that the joints overlap one another. The 8 in. by 10 in. posts which support the needles on the side walls and over the center columns are boxed around so that the lower layer of water-proofing shall be kept away from the posts at least 2 in. on each side. The 3 in. layer of concrete intended as a protective coating for the water-proofing against physical injury is next placed, and before the needles are removed the longitudinal stringers under the rails are posted on the main roof with 8 in. by 10 in. posts, set on 4 in. foot blocks about 5 ft. center to center.

The needles are now withdrawn and the posts supporting the needles removed. The asphalt is patched out so as to form a continuous sheet, and the upper layer of concrete is completed.

At the stations, where the street is carried on the structural steel as soon as it is placed, the method of procedure is quite similar. The posts are boxed around as in the former case, the asphalt sheet laid on top of the concrete jack arches, and the 3 in. protective layer placed. The permanent posts are then placed resting on the finished roof, and the temporary posts and boxing removed from the steel girders, and the lower layer of concrete carried up over the steel to the level of the bottom of the water-proofing, after which the asphalt layer is patched out as usual and the protective layer is completed.

After the boxing is removed so as to allow the placing of the lower layer of water-proofing, it is again restored prior to placing the upper layer at a distance of about 4 in. each side beyond the lower layer, so that the top layer will lap over the lower layer to form a continuous sheet.

Method of Steel Erection.

At Second Street Station the sewers and all of the station work were completed and the structural steel erected on the sides before the work on the core removal was begun. The top lift (about 8 ft. in depth) was then taken out of the core, and the transverse steel girders were placed in position from each side. These girders, which eventually rested on the center columns in the stations, were posted

down as each successive lift of the core was removed until sub-grade was reached, after which the concrete center footing was built and the columns erected thereon, and the cross girders riveted in place. After the cross girders were placed in the top lift the entire street load was carried on them while the work of excavation proceeded.

These transverse girders, which were spaced 6 ft. center to center, were temporarily bolted to the longitudinal girders at the sides, the other ends being supported on 12 in. by 12 in. timbers, 18 ft. long, placed in two lines parallel with the axis of the subway, and about 5 ft. from center to center. The needles, as they were known in the work, were posted down to the bottom.

No timbering other than the needles above mentioned and the posts supporting them was required in the core. The posts were 12 in. by 12 in. timbers, 16 ft. long, at sub-grade of the excavation. These posts were tied together transversely and along the axis of the subway with 3 in. by 8 in. planks, to prevent distortion or movement. Practically the same method of erection was followed at Fifth, Eighth, and Eleventh Street Stations. At Thirteenth Street Station the entire cut was timbered and the steel placed afterward.

All of the structural steel at the stations was placed with one or other of the derricks described earlier in this paper. A portable "A" frame was used for lowering the center subway columns, and a gin pole and portable winch were used in placing the steel work at the portal which was not accessible to a derrick.

The erection of the structural steel often presented great difficulties. Because of the fact that the material could not always be lowered into the place where it was required on account of the underground structures, it became necessary to get it in at any point at which a gap presented itself in the structures; it had then to be skidded along underneath to its proper place.

Portable electrically driven air compressors were used to supply air to the pneumatic hammers used for riveting.

Sewer Construction.

The building of the sewers generally required four distinct operations: 1st, the laying of the concrete invert; 2d, the placing of the brick lining in the invert; 3d, the building of the two side walls to the spring line of the arch; 4th, the placing of the arch. Wooden templets were used for forming up the invert, and wooden side forms were generally used below the springing line of the arch, and collapsible

steel forms were used for the arch in every case. The outside forms for the arch were generally built up as the concrete was placed, of 1 in. by 6 in. rough lagging on ribs cut from 1 in. boards 12 in. wide, and spaced 30 in. center to center.

Two sets of transverse reinforcing bars were used in the arch and side walls; one set was usually placed 2 in. above the intrados of the arch, and the other 2 in. below the extrados. These rods were set after the forms for the side walls were built to the spring line. They were supported on the center line of the arch at the proper height on 2 in. by 3 in. scantlings suspended from the trench timbers in notches cut so as to preserve the proper distance center to center, and by 1 in. by 3 in. planks fastened to the top of the side forms at the springing line of the arch.

The longitudinal rods were wired to the transverse rods in the proper position.

The collapsible steel arch forms were set on sills parallel to the axis of the sewer, framed together so as to form a carriage which was provided with cast-iron wheels or casters, so that the entire section of the arch after lowering the crown could be moved on wooden rails supported above the invert which were provided for the purpose.

The equivalent of 50 ft. of completed sewer, 7 ft. by 7 ft. in dimension, is the maximum length built in this manner in one day of ten hours.

Methods of Construction Considered.

It was early recognized that the one thing that stood in the way of rapid progress in the construction of the subway was the maintenance of the old Market Street sewer until such time as the new sewers could be put into operation.

As long as the old sewer in the center of the street remained in service, it was impossible to excavate for the subway proper, and the only work in connection with the subway that could be done while the old sewer was in operation, throughout its whole length, was the building of the side walls.

It may be of interest to mention one scheme that was devised for getting rid of the obstruction caused by the old sewer. It was proposed to begin operations on the new sewers on both sides of the street simultaneously, block by block, and to connect up the house services and inlets as the sewers were completed, and also to make temporary connection with the old sewer to the westward where necessary. It was also proposed to establish small pumping plants along

the line to pump the sewage and storm water from the several disconnected sections of the new sewers into the higher level sewers on the intersecting streets at Fourth, Seventh, Ninth, Twelfth Streets, etc. By dividing the new sewers into comparatively small sections, the quantity to be pumped at each point could be minimized. Work on the subway proper could then have been commenced at several points at the same time without waiting for the completion of any considerable length of new sewer, or even before the outlet of the new sewers was completed.

This scheme was considered in all its details, and the necessary computations of the increase in the drainage areas of the sewers proposed to be utilized was made, and it was found that if an amount of storm water due to a rainfall on the drainage area at the rate of 3 ins. per hour for a period of twenty minutes was deemed sufficient, the tributary sewers were all sufficiently large to accommodate the increased flow, and under ordinary circumstances this would have presented a splendid solution of the problem, and would have no doubt allowed of an earlier completion of the whole work, but the uncertainty of being able to put into instant operation the several pumping plants at any time that a storm might arise was deemed of sufficient importance, in view of the incalculable damage that might have ensued, to outweigh all of the good points in the scheme.

The only other feasible method was the construction of the subway following the building of the new sewers from the outlet continuously, and this method was therefore adopted.

Underground Structures Encountered.—As can well be imagined, the underground structures seriously interfered with the progress of the work of construction. In some places, particularly at the street intersections, where two distinct sets of structures were encountered, they were often in such number, and were so close together, and of such size, as to entirely preclude the idea of working a bucket between them for the purpose of removing the excavated material, and it had to be removed by a process of tunneling.

The material below the structures was either cast or wheeled to a point from which it could be taken to the surface in buckets in the usual manner. Often the space occupied by a duct manhole near a street intersection was used for the purpose of a shaft. The cables in the manhole were first drawn to one side and boxed in; after which the manhole was demolished and used for the purpose stated.

Some conduits, notably those made up of creosoted wood ducts, could be shifted to one side or the other without injury, but others, such as wrought-iron pipes carrying the Edison Company's light and power cables, were inflexible and could not be moved, but had to be maintained in position. Terra-cotta ducts, enveloped in concrete casings, were likewise immovable, and had to be supported in the timbering in practically the same position they occupied in the ground. All of the structures, conduits, and pipes were either blocked up from the trench timbering or suspended by wire cables or wooden hangers.

The high pressure fire service pipe, in addition to being blocked up from the timber, was firmly held in place by four 3 in. by 9 in. struts, abutting against the pipe in such a manner as to prevent any movement whatever.

The old abandoned wooden water pipes, and several lines of abandoned conduits, were removed as they were encountered in the excavation, and the two lines of 6 in. cast-iron water pipes, which have been in service about seventy-six years, are being replaced by 10 in. lines on each side of the street.

The 20 in. water distribution pipe, which is a modern structure, is being removed and relaid in the center of the street to allow the laying of a new line of ducts for the Keystone Telephone Co., whose old conduit had to be removed to allow of the work of constructing the subway and sewers.

Old Market Street Sewers.—Some special features connected with the underground structures encountered may be worthy of more extended notice.

The Market Street sewer system which had to be replaced was one that had not been built at one operation, but had been extended from time to time, much of it having been built before the consolidation of the townships, districts, and boroughs, which subsequently became the city of Philadelphia.

It was apparent that very little attention had been given to the grade of the invert, and no attention whatever to the hydraulic grade line due to a coincident storm covering the drainage basin and high tide in the river.

The sewer, excepting a small section built in 1898, was found to be in a badly dilapidated condition, and was often considerably distorted; the sewer invert in many cases appeared to be laid without the use of cementing material of any kind whatever.

Because of abrupt changes in the grade and defective junctions with sewers on the intersecting streets, a considerable portion of the sewer cross-section—at times as much as 50 per cent.—was found to be obstructed with the inorganic sediment which had been deposited during many years. The aroma arising from the decaying organic matter which covered this sediment deposited more or less recently was responsible for the nausea of many a passerby on the street sur-

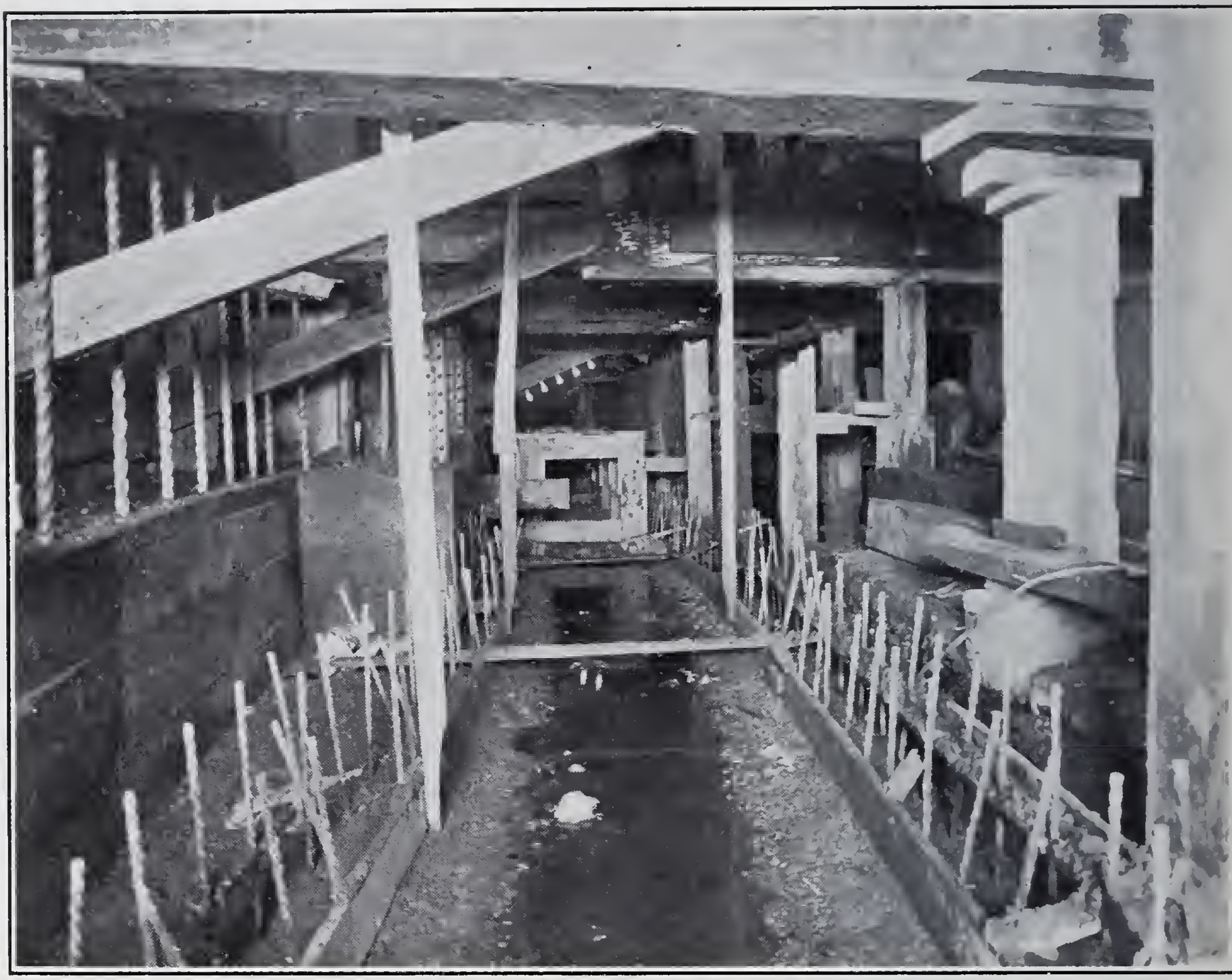


FIG. 14.—SECTION WEST OF THIRTEENTH STREET, NORTH SIDE, SHOWING SEWER.

face during the process of removing the old sewers, without his probably being aware of the cause.

The defects of this sewer herein outlined, as well as its fundamental defect of being too small to accommodate the flow, caused in time of excessive storm a backing up of the flow, and to this the specifications for the building of the new work called attention in a clause which pointed out that the sewer at times "worked under a head." It was therefore necessary, when the house services and other connections to the sewer were encountered in the excavation, to provide for

sealing them against back flow from the sewer. The only successful method discovered was the relaying of the entire connection with a temporary one of light weight cast-iron soil pipe with leaded joints, across the excavation, and this method was subsequently resorted to on the entire work.

As the new sewers were completed the house drainage was turned into them, as well as was the flow from the old sewer. But it was impossible to build the new sewers continuously because of obstructions, and therefore the flow was turned into the north and south sewers alternately as the gaps were closed up, and the sewers became continuous to the river.

The temporary connections between the old and the new sewers were made at the following places:

West of Fourth Street into the north sewer.

East of Eighth Street into the south sewer.

East of Tenth Street into the north sewer.

At Eleventh Street into the south sewer.

At Twelfth Street into the south sewer.

At Thirteenth Street into the north sewer.

Because of a gap in the south sewer west of Eighth Street which could not be closed at the time, the entire sewage flow between Eighth and Thirteenth Streets on the south side was pumped across the street into the north sewer, which had been completed to that point for a period of over six months. Two 4 in. centrifugal pumps, electrically driven, were used for this purpose—generally one pump was of ample capacity to handle the flow, and the other was provided as a reserve.

The working capacity provided by the new sewers is about four times that of the old sewer when the latter was clean and unobstructed.

Cast-iron Water Distribution Pipes.—Among the pipes which were found in service when the subway excavation was made were the two lines of 6 in. cast-iron bell and spigot water pipe, one on each side of the street, which were laid in the year 1822, and are among the first cast-iron water pipes laid in the city. There was no cast-iron water pipe made in this country at the time, and the pipe composing these two lines was brought over from England. This pipe was in 9 ft. lengths, and the bells were somewhat deeper than those of the present day. It was cast in a horizontal position, and the thickness, therefore, could not be maintained as uniform as in vertically cast pipe, which all specifications call for today. The pipe at best varied from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. in thickness. As we found it, it was ready to go to

pieces on the slightest provocation, in many cases without any provocation at all. It was possible to drive a nail into the best of it with very little exertion.

Bell Telephone Conduit.—The Bell Telephone conduit, which occupied a position on the south side of the street, varied in dimension at different points, and the average size was not far from 4 ft. square. This conduit seems to have been an experimental one, and was composed of several quite distinct types of ducts. A portion of the line was fiber duct, another of creosoted wood duct, another of terra-cotta duct, and still another of wrought-iron pipe with screw joints. All of these ducts except the wooden ones were encased in concrete, and before the conduit could be shifted or raised where it interfered with the construction work it had to be stripped of its concrete envelop. This was a tedious operation, and had to be conducted in such a way as not to interfere with the service. At the time of stripping off the concrete the ducts not occupied by telephone cables were removed. The new line of the Bell Telephone Co. is being built of terra-cotta multiple duct (6 way) encased in concrete, and in many places it occupies practically the same location in the street as did the original. It is often necessary to either shift the old ducts aside or to jack them up; in which case each individual duct is suspended from the upper cross-brace with wire during the process of laying the new line.

High Pressure Fire System.—One of the conditions incident to the work of construction was the relaying, in its entire length, of the Market Street line of high pressure fire system with its many and intricate cross-connections.

The old 16 in. line was dismantled in sections only after the new one was laid and ready to connect up: one of the conditions imposed being that not more than one fire hydrant at a time be put out of service. Both the old and the new lines were temporarily supported in the timbering in such a way that despite the fact that the line is at all times subjected to a pressure of 50 lbs. per sq. in. when not in service, and in time of fire to a pressure of from 250 to 300 lbs. per square inch, in not a single instance was any interference with the service sustained. The new line and all the hydrant connections were tested prior to putting into service to a pressure of 400 lbs. per sq. in. As long as it was supported in the timbering the line was patrolled night and day for the purpose of observing its condition.

Because of the lack of circulation in the line when not in actual fire service, it was deemed expedient to protect it against freezing

with some nonconducting covering, and for this purpose the entire pipe line and all its connections were wrapped with two 1 in. layers of hair felt, wired on and covered on the outside with tar paper to protect the felt from the rain or melting snow. The edges of the tar paper were lapped at least 6 in., and hot tar applied to the joints to make the covering continuous.

The same system of insulation was applied to all the water distribution pipes and house services except the 20 in. distribution line, which our experience indicated would not be affected by the cold, and which judgment the actual experiment sustained.

Old Wooden Water Distribution Pipes.—On both sides of the street the excavation brought to light the old wooden water pipes which were laid in the year 1799. These pipes, which were simply hemlock logs with a 6 in. hole bored through them, were laid in continuous lengths, the end of one pipe being cut so as to fit into the adjacent one, and were first put in service in the year 1801. Water was pumped at Center Square Water Works, now the site of the City Hall. The wood was in most cases discovered to be sound.

Among the conduits encountered was that of the National Underground Electric Co., laid in 1883–84, from Second Street to City Hall, said to be the first electrical conduit laid in the city of Philadelphia. It consisted of about twenty 2 in. dia. tin tubes or pipes embedded in a bituminous composition. Also the iron pipe conduits of the Brooks Underground Electric Co., which when in service were filled with paraffine or some similar substance to provide insulation for the wires, reservoirs or stand pipes having been erected on the curb to keep the pipes supplied.

Contractors' Plant.

Sixteen electric hoists were used on the excavation. Because of the speed with which it was intended to push the work to completion, it was not considered prudent to place the orders for all the machinery with one concern, but rather with several, and accordingly the following arrangement of hoist and motor was secured:

Four Lidgerwood hoists and General Electric motors.

Two Dobblie hoists and Westinghouse motors.

Four Maine hoists and Maine motors.

Six National hoists and C. &. C. motors.

The pumping plant consisted of:

Five 4 in. centrifugal pumps of the Gould and Morris make.

Five 3 in. centrifugal pumps of the Rumsey make, and
Two $1\frac{1}{2}$ in. Franklin turbine pumps.

Each pump was driven by an electric motor of either the C. &. C., the Westinghouse, or the Browning make, and the $1\frac{1}{2}$ in. and 3 in. pumps were mounted with the motors on cast-iron bases. The 4 in. pumps and motors, which were mounted on heavy wooden bases built on the work, had originally been arranged to be belt driven, and had been converted in the company's shops into direct connected machines. Comparatively little water was encountered in the excavation. The 4 in. centrifugal pumps handled the greatest quantity of water at any place, excepting at the site of the permanent pump well at Fifth Street Station, where two 4 in. pumps were required to handle the water encountered in the quicksands at that place.

In all forty (40) electric motors, ranging from $3\frac{1}{2}$ H. P. on the smallest pump to 25 H. P. on the hoisting machines, were used on the work.

In the saw mill were a 30 in. and a 16 in. cut off saw for making the wooden wedges used in timbering, and a jig saw used in sawing out the ribs for the concrete forms. Each saw was driven by an independent motor.

The necessary shops were provided adjacent to the work for the purpose of making repairs to the plant as well as for various other work incident to the construction of the subway. These shops were generally well equipped with electrically driven machine tools, and formed a very useful adjunct to the contractors' plant. The following shops were provided: machine shop, blacksmith shop, rod bending shop, electrical shop, carpenter shop, saw mill.

In the machine shop were made all the repairs to the pumps and hoisting machinery and concrete mixing machines used on the work. As is well known, these repairs are usually very costly, but they are reduced to a minimum where well-equipped shops are provided as a part of the plant. In the blacksmith shop were made all of the steel wedges used in underpinning, a power hammer being provided for the purpose. The sharpening of all tools and the rebuilding of the iron-body wheelbarrows, etc., was done in the smith shop. In the electrical shop the small repairs to the motors were made. In the saw mill the wooden wedges used in timbering were made of scrap timber and waste. It is estimated that upward of one million wedges were used on this work.

A wharf was provided at which was received and stored the direct shipments of lumber from the south. A general storage yard opposite

the wharf with sidings from the main tracks was also provided. An electric hoist operating a stiff leg derrick with a 45 ft. boom was used for unloading structural steel from the cars. At this yard was also located a cement storage house of twenty-six cars capacity.

Working Forces and Progress.—The greatest number of men employed directly on the work in any day (twenty-four hours) was not far from 2000; this means that during the period of our greatest activity between 8000 and 10,000 persons were dependent on the prosecution of the work for their sustenance. When it is considered that the busiest period of our existence occurred on this work just about the time of the financial depression from which the country is just recovering, it is seen at once that the construction of the subway has already proved a factor for good in this community.

The maximum number employed on the excavation was about	1000	men
The maximum number of timbermen employed was about	160	"
The maximum number of carpenters employed was about	125	"
The maximum number of men employed on concrete was about	300	"
The maximum number of cement finishers was about	35	"
The maximum number of structural steel erectors employed was about	95	"
The maximum number of engineers, motor runners and pumpmen employed was about	40	"
The maximum number of machinists, blacksmiths, pipe fitters, etc., was about	30	"
The maximum number of electricians, riggers, watchmen, employed was about	35	"
The maximum number of underpinners employed was about	50	"
The maximum number of drivers employed was about	200	"
The maximum number of double teams employed was about	200	"

Owing to the obstructions encountered and to the incidental work it is difficult to make a direct comparison between the progress of the work described in this paper and that built elsewhere in this country. The fact remains, however, that the construction of nearly 6000 feet of subway with 5 stations, and of nearly 13,000 feet of sewers, and the rearrangement and rebuilding of the entire system of underground structures, as well as the underpinning of the buildings, and various other work incident to the construction, in the short space of time of two (2) years, is an accomplishment which compares very favorably with the best in the sphere of construction of similar works.

In conclusion it may be said that—

The subway is the fruition of the natural growth of rapid transit

facilities of the age. It is in this particular case an incalculably far greater advance in this long-sought direction than was the substitution of the cable road by the surface trolley system, or than was the former system over the old horse-car roads which preceded it; and the natural question is: Will it be the last? This we must leave to the future to determine.

PAPER NO. 1056.

THE DESIGN OF THE CENTERING FOR THE 233-FT. ARCH SPAN, WALNUT LANE BRIDGE, PHILA., PA.

GEORGE MAURICE HELLER.
(Visitor.)

Read April 4, 1908.

IN contributing the following paper to The Engineers' Club of Philadelphia it is hoped that the data presented will prove interesting to the members, not only by reason of the great advance it makes in engineering science, but also by reason of the proper civic pride which

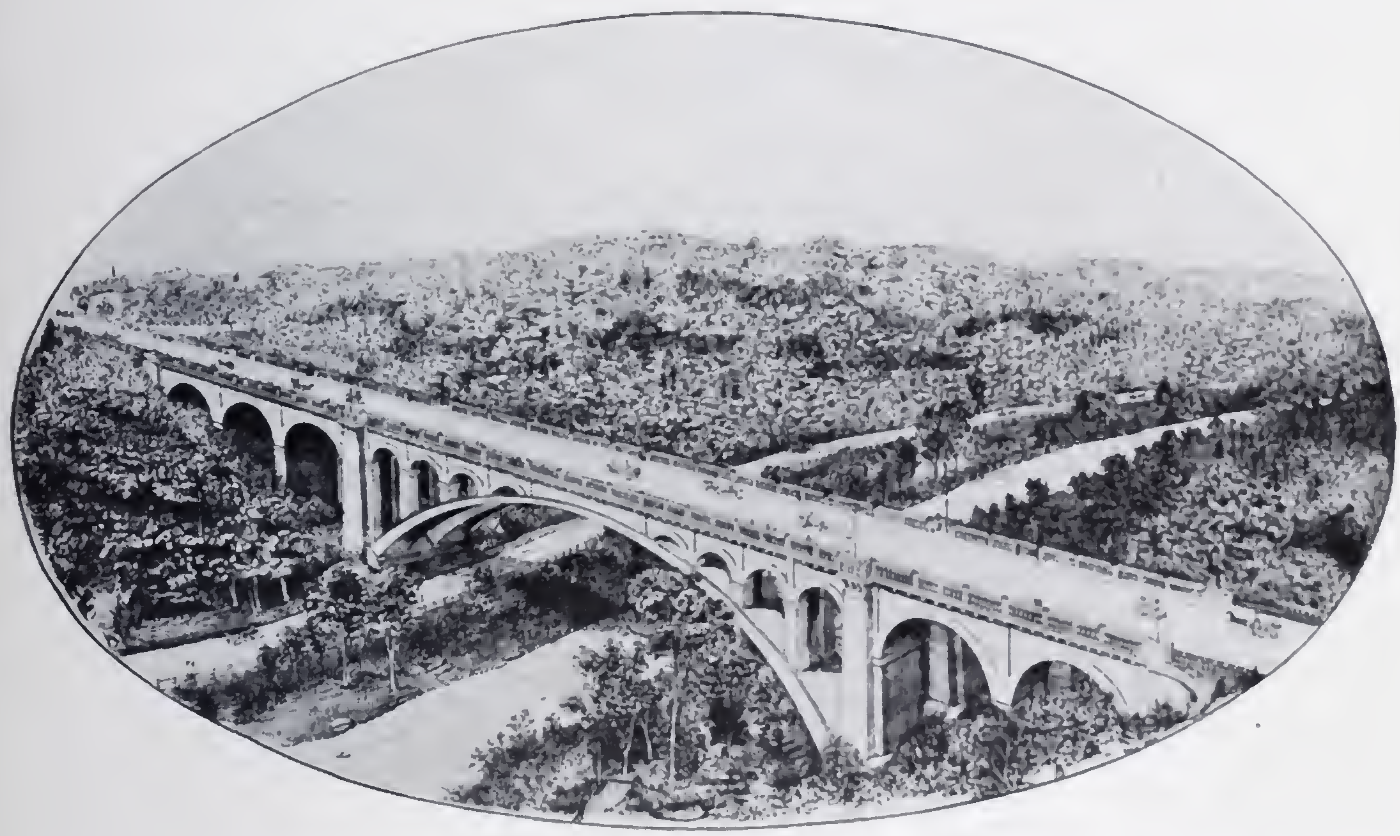


FIG. 1.—PERSPECTIVE VIEW OF THE WALNUT LANE BRIDGE OVER THE WISSAHICKON CREEK, PHILADELPHIA.

our own native city has in undertaking that great and notable structure.

It can be fairly stated that men who are engaged in accomplishing the world's work, and while so engaged accumulate the peculiar experience inherent in such work, should consider the obligation which they

rightfully owe to their fellows, and, as far as they are able, make their experience available.

In the present case of the design of the main centering it is to be remarked that it is necessarily of a temporary nature, and by reason of this fact its importance only becomes evident when the structure itself is important or presents unusual difficulties. Usually it receives but little attention in ordinary work, but when the work assumes massive proportions, then the cost of the centering alone forms a considerable item of the total cost, and as such demands the most careful consideration and the most diligent care and oversight in the design.

In considering the present paper, devoted to the design of the main centering, it can be readily conceived how that each step in its design would be most carefully studied, inasmuch as the magnitude of the work and all its attendant conditions, which were of a nature not hitherto encountered in engineering practice in this country, should be met and provided for on a scale commensurate with such requirements.

Dimensions of Arch.

The main arch of the Walnut Lane Bridge consists of two arch ribs, each 18 ft. wide at the crown and 21 ft. 6 ins. wide at the skewback; these ribs are spaced 34 ft. center to center, and are 5 ft. 6 ins. deep at the crown and 9 ft. 6 ins. deep at the skewback; the span is 233 ft. in the clear, and the height of the soffit at the crown above the springing line is 70 ft. 3 ins.

The two main ribs carry spandrel piers and a series of spandrel arches upon which the spandrel walls are built up to the height to receive the floor, which consists of steel beams with concrete arches between, and it is upon this floor that the roadway and sidewalk paving is laid, the roadway being 40 ft. wide and the two sidewalks each 8 ft. wide. The height of the soffit of the arch above the surface of the creek is about 136 ft., while the roadway of the bridge is about 14 ft. higher, making about 150 ft. The site of the bridge chosen is admirable and advantageous.

Design of Centering.

The features therefore presented in the problem of designing suitable centering for the main arch span were, to support during construction an arch rib whose weight per horizontal foot, exclusive of spandrels, varied from 20 tons at the skewback to 8 tons at the crown, or a total

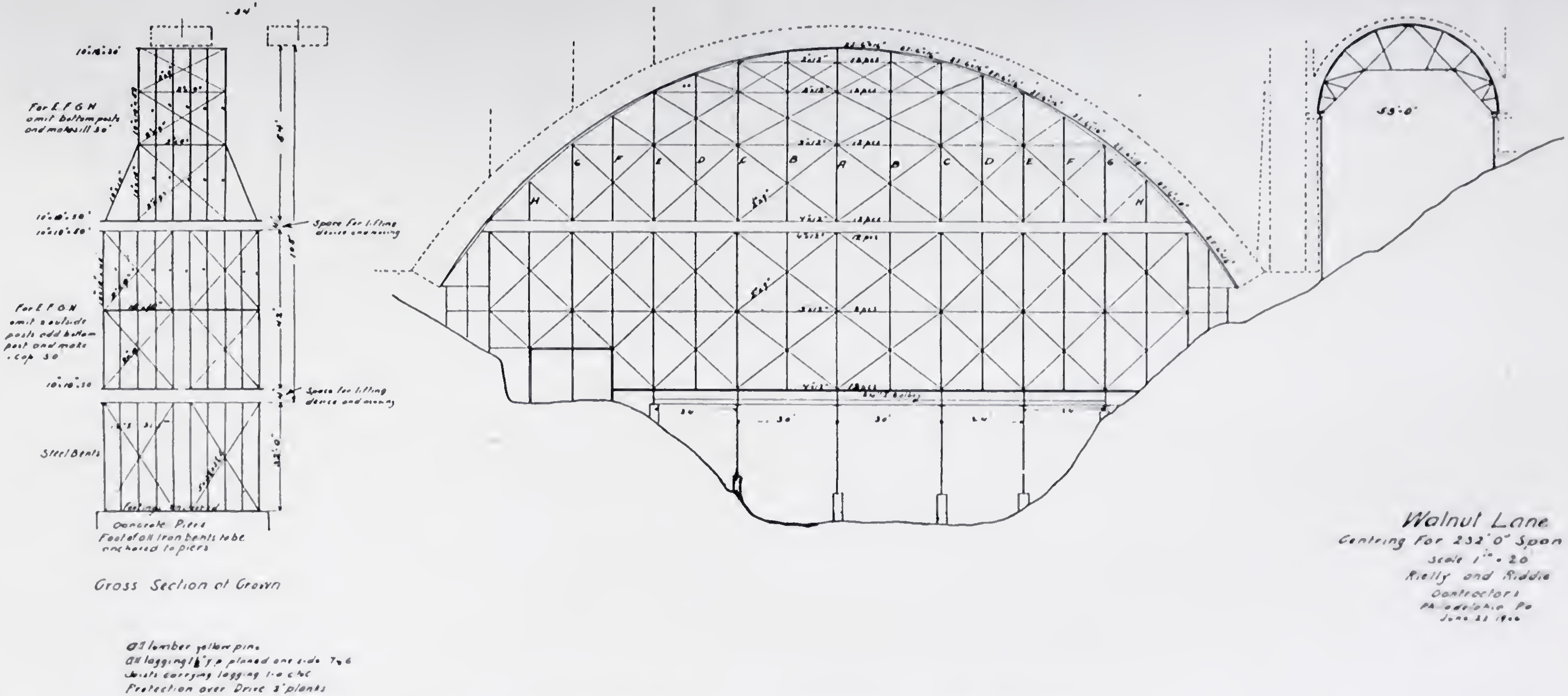


FIG. 2.—ELEVATION AND CROSS-SECTION OF THE CENTERING.

of 3100 tons, making an average weight of arch rib of 14 tons per horizontal foot. Besides carrying this load it was to resist wind pressure covering an area of 232 ft. long by 136 ft. high; to guard against possible freshets; to provide for a transverse movement of 34 ft., together with means of adjustment and release of supports; and to reduce the deflection of the arch during construction to a minimum.

In considering the problem of a design suited to the conditions, it is but natural that various designs would present themselves, each having some distinctive merit, and that great care would be required to choose that one embodying with certainty the most vital features involved. Therefore it was thought unwise to use any truss system to carry the weight of the arch during construction, for this would naturally involve deflection within the truss itself, while with a number of vertical supports each carried down to firm rock, these supports would distribute the load over a great number of points and so avoid deflection and consequently preserve most accurately the proper profile of the arch, so that when finished, the line of profile would not be marred by any irregularities in its curve.

These considerations led to the adoption of the present design, in which each supporting point was made sufficient for its own part and independent of all others and capable of individual adjustment, thereby insuring the accurate profile of the arch at each point of support.

It is also necessary, while considering the nature of the design, to remark the fact of the arch itself being composed of two independent and separate ribs. This feature allowed the construction of each rib by itself and so presented an opportunity of reducing the cost of the centering by permitting one arch rib to be constructed first on centering necessary for one rib, and then, when the arch rib is completed, to move the same centering transversely so as to serve for the construction of the adjacent arch rib. This feature of construction was embodied in the design, and it was found not only to be feasible, but also simple and easy of action, even though the mass of timbering was so great and covered so large an area. It was also thought proper to use steel in the construction of the bottom of the centering, for, as a material, it afforded better facilities for making joints capable of withstanding possible vibration in moving, and it formed a firm foundation, all parts of which acted together as a unit and allowed the whole mass to be moved true to line and without distortion or accident to its new position.

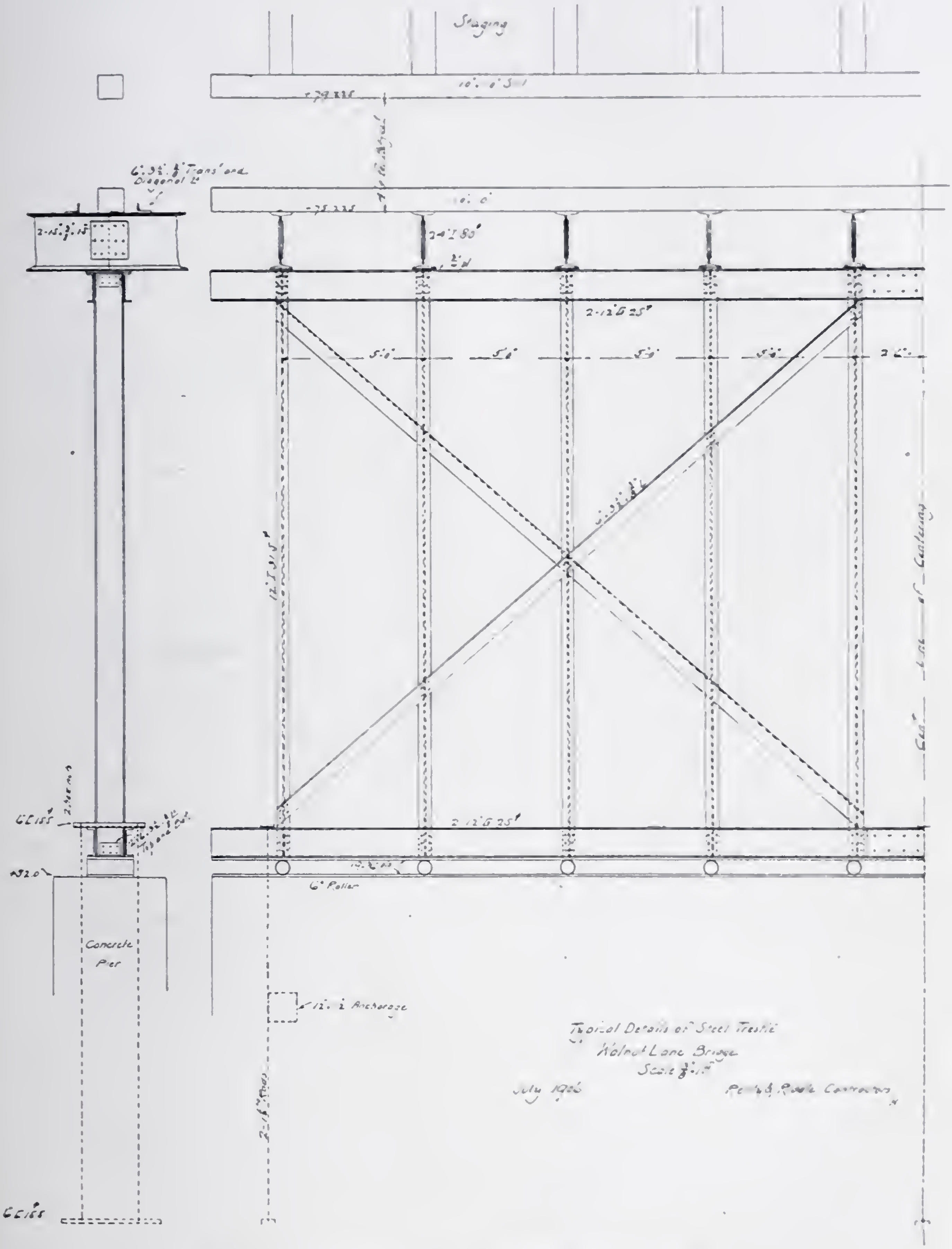


FIG. 3.—DETAILS OF THE STEEL TRESTLE.

Base of Centering.

Beginning therefore with the base of the centering, the steel trestle supports were spaced 24 ft. and 30 ft. apart and were carried on concrete piers founded upon and doweled into the solid rock. These piers were carried up to a uniform height above all danger of freshet, and they formed the basic foundation upon which the whole mass of steel

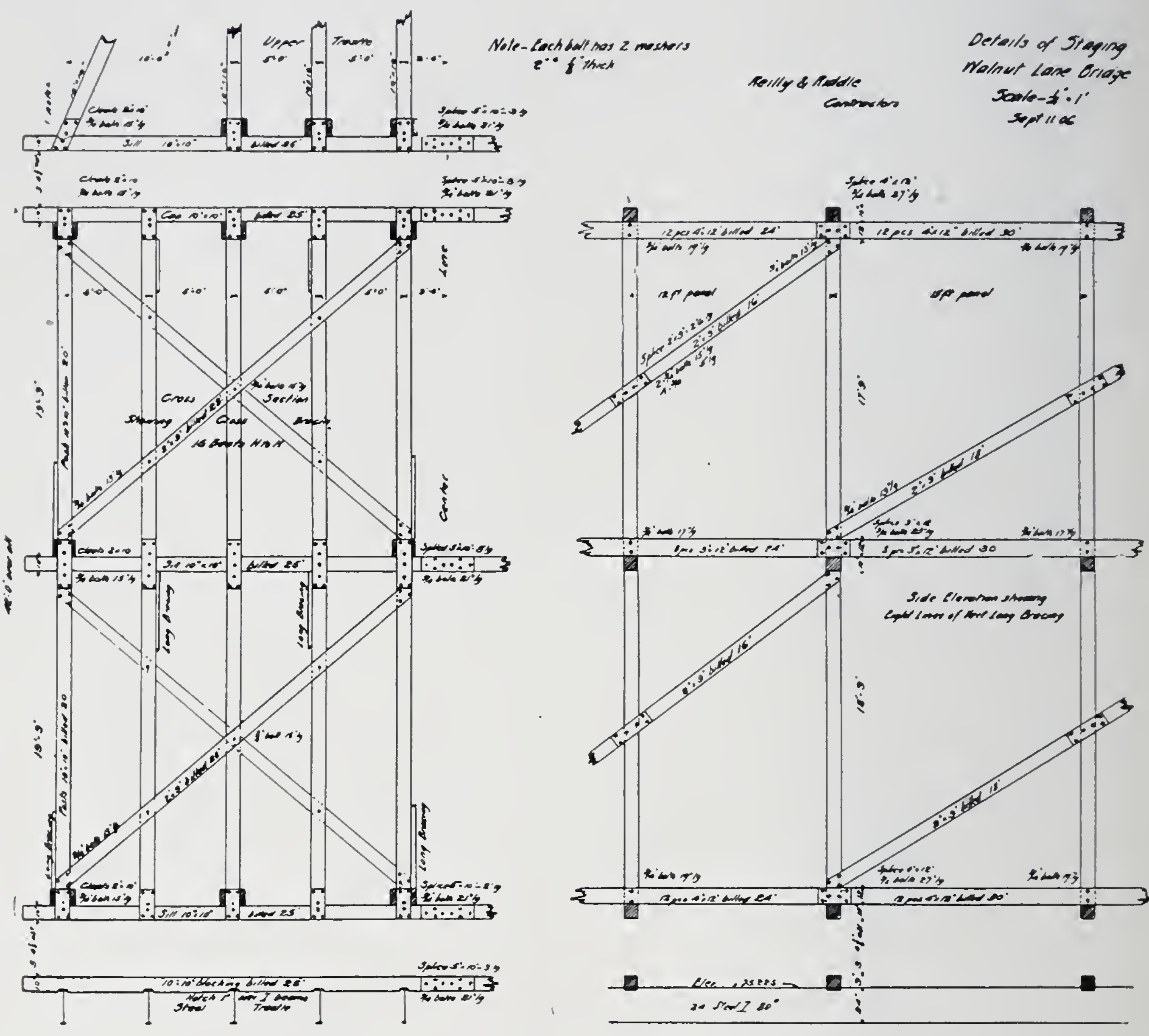


Fig. 4.—Details of the Staging.

and timber was designed to move. Each steel trestle was securely anchored into its pier by $1\frac{1}{2}$ inch steel rods, and these rods served to guard against freshets and wind and were released when the centering was moved.

Provision for Movement.

The movement of the centering was accomplished by placing on each pier a series of ten steel rollers, each 6 in. in diameter, rolling on

steel plates built into the tops of the piers; each roller was capable of bearing in safety 10 tons, making 100 tons, which was the total maximum weight at the center pier to be moved. The steel bents rested upon these rollers, and upon completion of the erection of one rib of the arch they were all moved in unison by placing jacks between the bottom end of each steel bent and a studded anchor chain which formed a cradle or saddle against which the jack worked, the ends of the chain being attached to timbers previously built into the piers for that purpose: this method of translation proved to be quite effective,

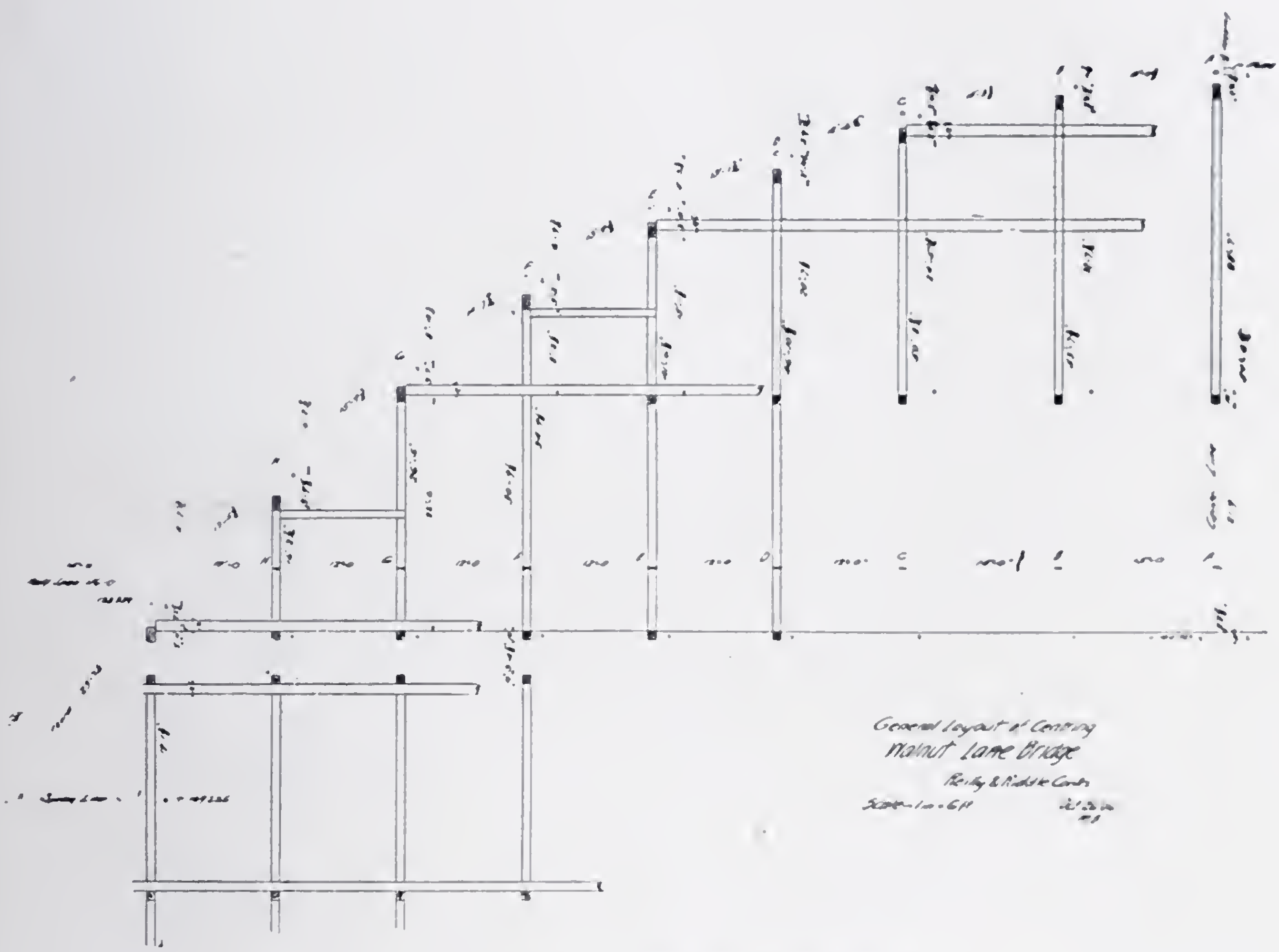


FIG. 5.—LAYOUT OF THE CENTERING.

and the whole distance of 34 ft. was covered in the space of three days.

The total weight moved can be fairly stated to be about 1000 tons. This amount is found by taking the total weight of bolts, steel trestle, and timber trestle, and allowing in the case of timber 5 lbs. per ft. board measure, the timber being probably very heavy from the absorption of water from the structure, This great weight, covering a length of say 230 ft. and a width of 50 ft., was moved by jacks having a sum total capacity of 345 tons acting at fifteen several points.

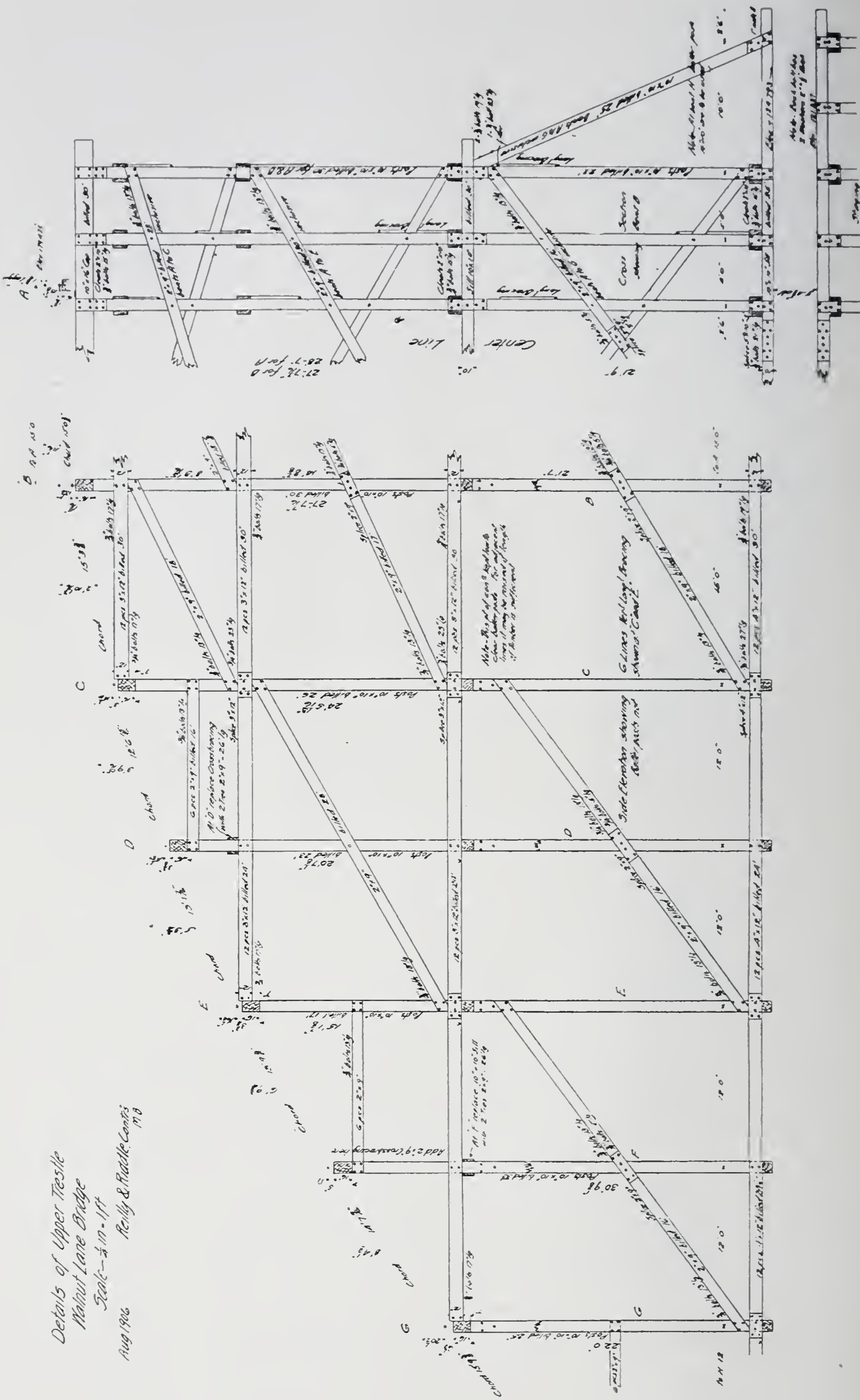


FIG. 6.—DETAILS OF THE UPPER TRESTLE.

Timber Trestle.

Upon the steel trestle and its floor of 10 lines of 24 in. steel beams the timber trestle is supported, the bents being 12 ft. and 15 ft. apart. This timber trestle is made in two portions, the lower portion, called

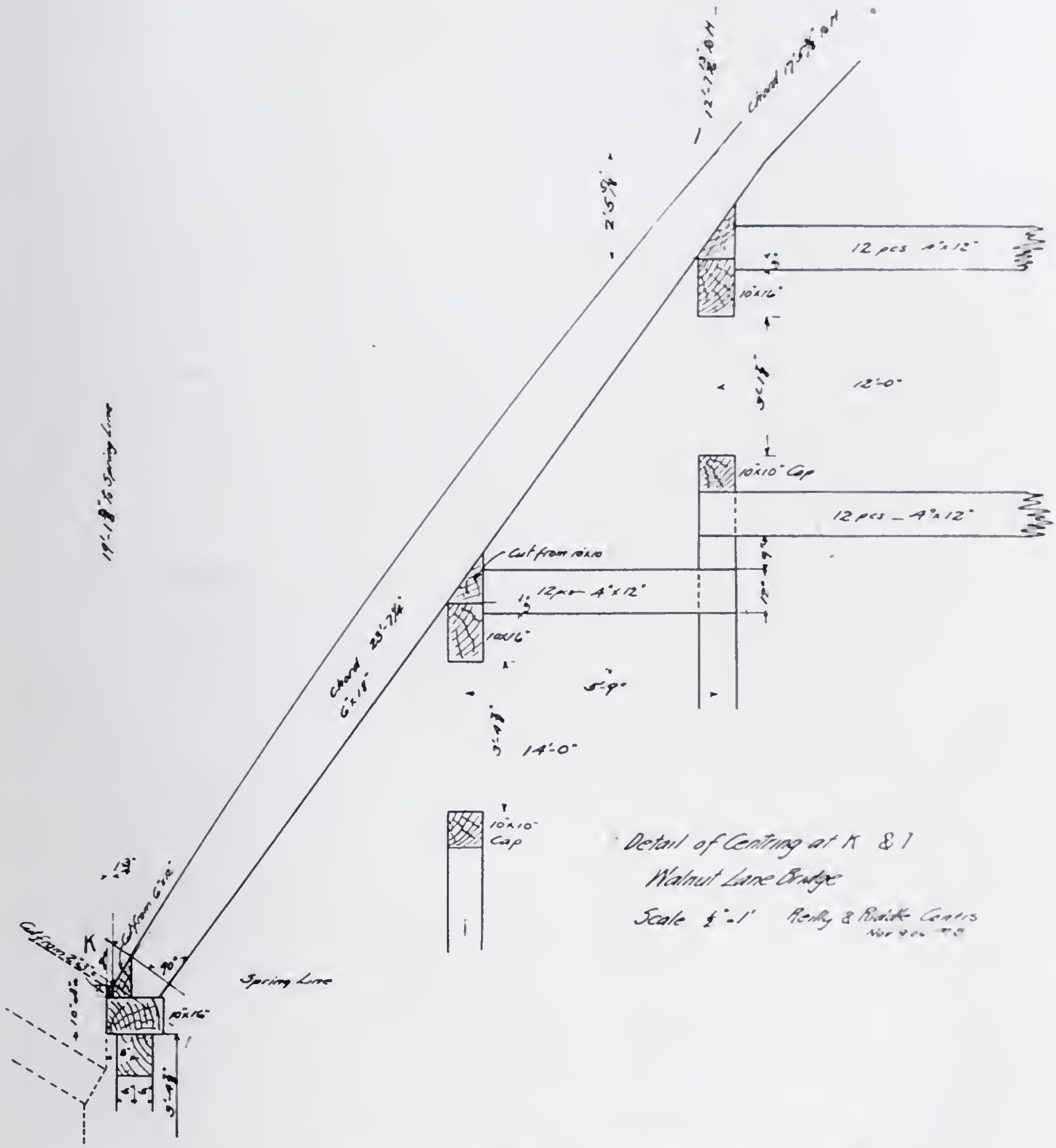


Fig. 7.—Details of Centering at the Skewback.

the staging, being of uniform height, with its posts, caps, and sills of 10 in. by 10 in. timber, and the upper portion, called the upper trestle, of varying height to suit the soffit of the arch with its posts and sills of 10 in. by 10 in. timber and caps of 10 in. by 16 in. timber. These

caps carry the 6 in. by 16 in. and 6 in. by 18 in. timber joists spaced 12 in. on centers, dressed to the curve of the arch. Upon these joists the $1\frac{1}{2}$ in. tongued and grooved lagging is laid, which completes the

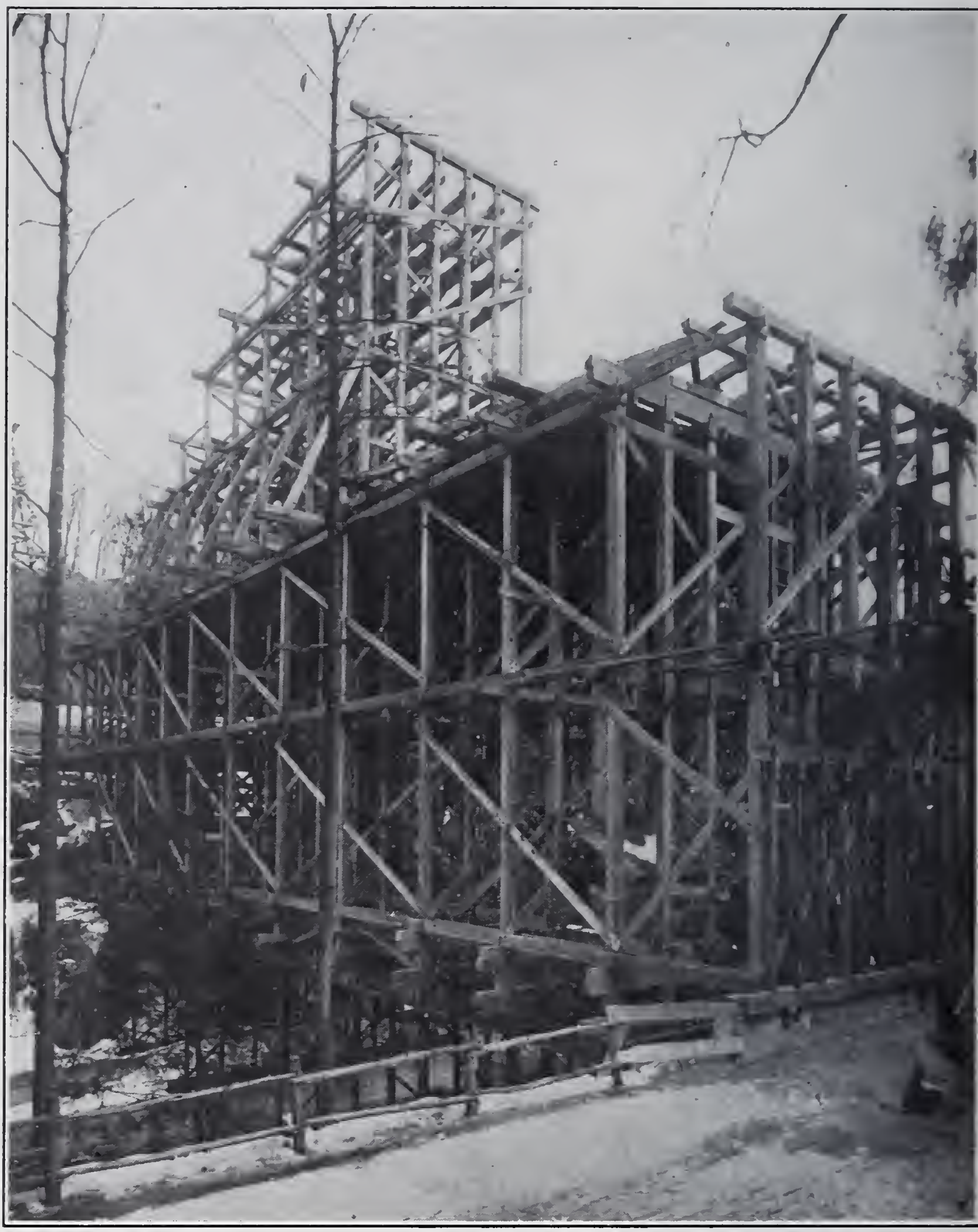


Fig. 8.—End View of the Staging and Upper Trestle.

construction of the centering. All timber was of yellow pine and thoroughly braced and bolted throughout with 2 in. by 9 in. braces and $\frac{3}{4}$ in. bolts.

The horizontal strains developed in the centering were provided for by introducing in the framing 3 in. by 12 in. and 4 in. by 12 in. horizontal timbers at different elevations, where they would be most effective in maintaining the proper equilibrium, horizontally, of the arch rib during its various stages of construction; these timbers were continuous from end to end of the horizontal elevation at which they were placed and were thoroughly spliced, butt-jointed, and connected to the vertical trestle bents throughout their length, serving also as a

Fig. 9.—Side View of the Centering Near Completion.

longitudinal tie between the trestle bents themselves. Usually the framing is so arranged that the horizontal strains developed are resisted by inclined posts mortised into the verticals, but in the present centering we remark the entire absence of such timbers, and in their place horizontal timbers were provided having a definite action which would be more effective than if inclined; generally horizontal string pieces are used, acting simply as string pieces in conjunction with the inclined struts, but in the present case entire reliance was placed in the direct acting horizontal timbers as being most effective; the

present centering is believed by the writer to be the first where this principle was rigorously adhered to.

Means of Adjustment.

There were two spaces of about 4 ft. each left for adjustment at each point of support, the lower one between the floor of the steel trestle and the staging, and the upper one between the staging and the upper trestle. The upper one was used for adjusting, by means of jacks and wedges, to proper height and for releasing when desired, while the lower one was added mainly for emergency use, though, fortunately, it was not required at any time; after the centering was erected true to line and height, the whole centering was still further raised to about 2½ ins. above normal height at the crown, gradually diminishing to zero at the skewbacks; this was to allow for settlement of the centering under the weight of the arch rib. At the completion of the final keying of the masonry of the arch rib, it was found that the soffit of the centering at the crown had finally settled to 1 inch below normal height, making a total settlement of the centering of 3½ ins. at the crown: this measurement was taken at the time the centering was removed.

Framing of Joists.

A feature of great interest will be found in the manner of supporting the lagging, which forms simply a platform upon which the masonry of the arch is formed during its construction. This platform can be formed in several ways upon the vertical supports of the falsework itself, but in the present case it was thought best to frame the platform so that each vertical support would carry its own load without any connection with adjacent supports; there is therefore in each span a series of joists laid parallel to the span of the arch and extending only from one support to the next support, and upon these joists the lagging is laid. In the framing of these joists they presented an opportunity of utilizing them as a continuous compressive member, which, following the line of the intrados of the arch from end to end, would assist the centering to that extent, and while this assistance was more or less indeterminate, yet it was made use of: to secure such combined action of these joists in continuous compression they were not jointed end to end in a butt joint bearing, but each series of joists was united to the next series by 3 in. oak tree-nails 2 ft. 6 ins. long, the holes for which were accurately bored to templet, thus insuring effectiveness

in action and accuracy in profile. This method of utilizing the joists in continuous compression is believed by the writer to have been used for the first time in the present centering.

FIG. 10.—END VIEW OF THE CENTERING NEAR COMPLETION.

UNIT STRAINS.

Having described in detail each vital feature in the design with the steps leading up to the adoption of each, we may take up the more technical part relating to the proportioning of the various parts.

The unit strains allowed in timber and steel were the usual ones allowed for permanent work; no reduction was made on these, for the reason that the centering had not only to serve for the construction

Fig. 11.—Masonry of the Arch Rib in Course of Construction.

of one arch rib, but had also to serve, under deteriorated conditions, for the second arch rib, and the whole service covering a period of about a year; besides it was necessary to allow for inequalities of distribu-

tion in the weights borne, so that these unit strains could withstand an increase of 50 per cent. upon the normal strain should this contingency arise, and yet be safe.

The following unit strains were used: For yellow pine timber, beams 1200 pounds per sq. in. on extreme fiber; posts $1200 \div (1 + \frac{L^2}{1200\ D^2})$ pounds per sq. in.

For structural steel, beams 16,000 pounds per sq. in. on extreme fiber; posts $12{,}000 \div (1 + \frac{L^2}{36{,}000\ r^2})$ pounds per. sq. in. Rollers $400 \sqrt{d}$ pounds per lineal in.

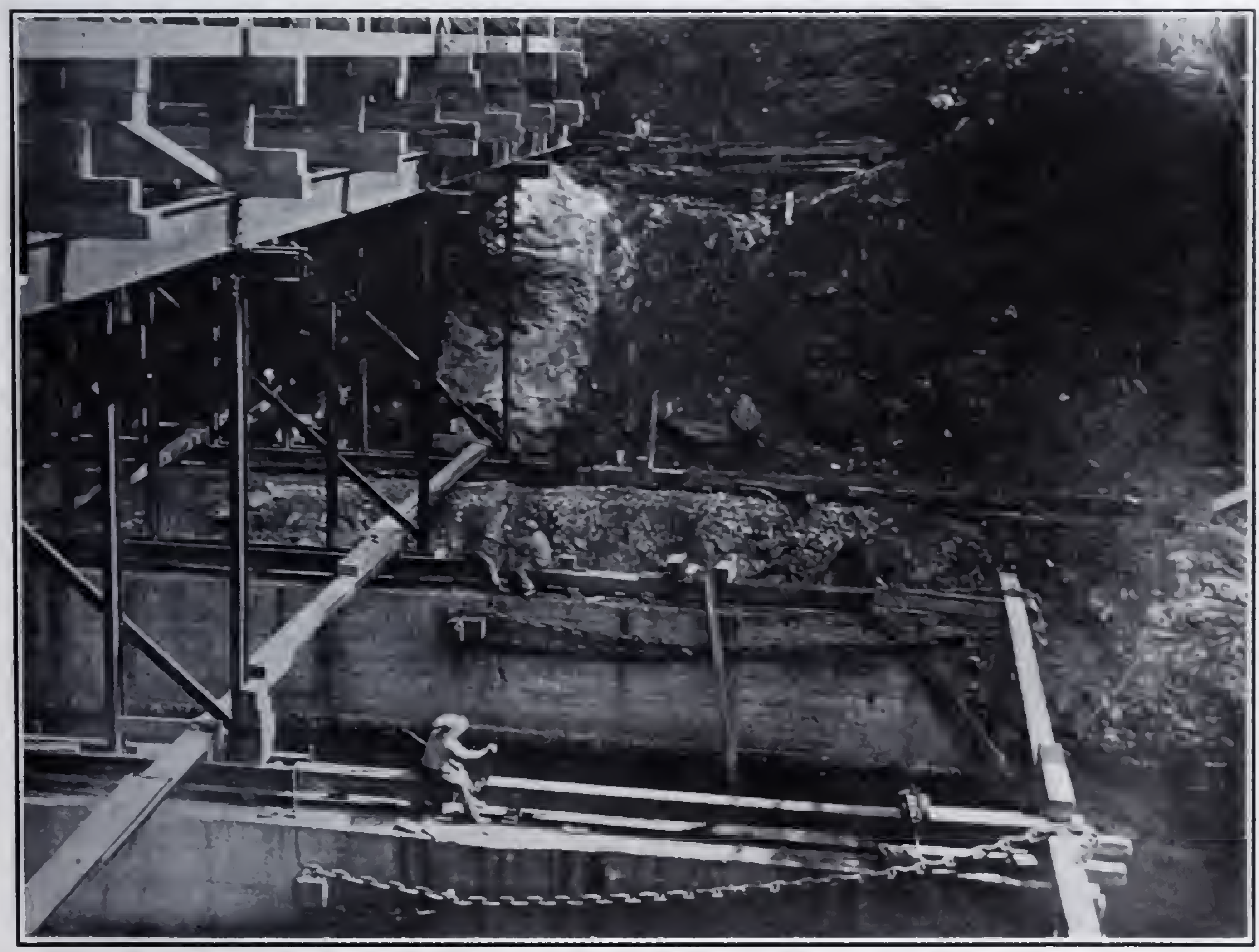


FIG. 12.—METHOD OF MOVING THE CENTERING.

In above formulæ, L is the length, D is the side, r is the radius of gyration, and d is the diameter—all dimensions being in inches.

RELEASE OF CENTERING.

The completion of any arch masonry and the release of its centering are always matters of great interest, both in regard to the arch and also in regard to the manner of release and the consequent action of the arch and centering individually; it is always a critical time and a

period of prime importance. In the present case the masonry of the first rib was required to remain on the centering for a period of at least one month after the final keying, after which the centering was allowed to be released and removed into position for the construction of the

Fig. 13.—Movement of the Centering at the West Skewback.

second rib. In releasing the centering the wedges at the skewbacks were first made entirely clear in order to prevent the arching or binding of the lagging at the haunch ends against the arch rib; after this, the whole system of wedges at the base of the upper trestle was

slightly lowered in continuous succession, beginning at the center and advancing outwardly, and simultaneously each way to the skewbacks; after this was done, the operation was repeated in the same manner, making each separate point entirely clear of the arch rib from the center each way to the ends. This system of release was thought to be most proper in accomplishing the desired object of gradually causing the arch rib to assume and perform its proper function in its entirety. Upon the complete release of the centering it was found by means

FIG. 14.—MOVEMENT OF THE CENTERING NEAR COMPLETION.

of leveling instruments trained on targets placed at various points on the face of the arch rib, that the crown settled but one-eighth of an inch (after the support of the centering was entirely removed). This is no doubt a matter of sincere congratulation, and well bespeaks the conscientious care taken both in the design of the arch itself and in its consequent method of construction. The city of Philadelphia, through its Bureau of Surveys, and the contractors for the construction of the work—Messrs. Reilly and Riddle—deserve great credit for the success which has rightfully crowned their labors.

Economy of Design.

It is well to state that the nature of the design was such as to allow of its fabrication on the site by the contractor. This is thought to be an important item financially. The style of the construction, while effective, was in the main essentially simple, no intricate features were involved, and the workmanship demanded, while being accurate, was still made simple by means of templets, which, being made in multiple parts, thereby reduced the unit of cost. In short, every effort was made to make the design not only effective and successful as an engineering problem, but equally so as a financial one; the work, it is believed, has accomplished both.

Quantities of Material.

It may be of interest to state the quantities of material used in the construction of the centering:

Bolts, washers, nails	33,000 lbs.
Steel trestle and its floor	232,000 lbs.
Lagging and Joists	88,000 ft. B. M.
Upper trestle and bracing	116,000 ft. B. M.
Lower staging and bracing	136,000 ft. B. M.
Concrete piers	1,000 c.y.

And for a comparative item to add

Concrete in one arch rib	1,550 c.y.

Comparative Data.

It is a noteworthy fact that engineering literature is peculiarly deficient in data regarding the centering of arches, and it is therefore difficult to compare one design with another, even though there may be some general features in common. This can only be realized when actually engaged in such inquiry; in the first and main case the data is not readily accessible, and even when made so, it is so limited as to afford little assistance, and in general it may be fairly stated that the contingent circumstances in each case are so various as almost to forbid any generalization.

Plauen Stone Arch Bridge.

In the centering of the Plauen Stone Arch Bridge, span 295.27 ft., rise 56.41 ft., illustrated in "Engineering News," Aug. 17, 1905, it is stated that one cubic unit of timber was used for every two cubic units of masonry; therefore, taking this as a guide, we find that the

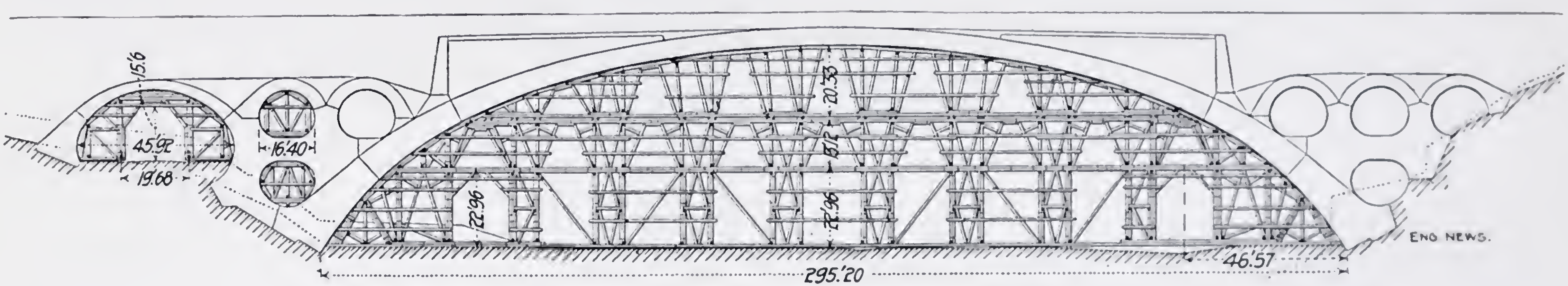


FIG. 15.—CENTERING FOR THE PLAUEN STONE ARCH BRIDGE.

Plauen centering was quite shallow, and extended only to springing line; also that the arch ring was built up in its complete depth in one operation, and so requiring the full support of the centering until final keying; therefore with this data we can make a fair comparison with the present Walnut Lane centering, for both have to maintain the full support of the arch until keying, and they differ only in height of centering; therefore, making the proper allowance for this feature in the Walnut Lane centering, we find less timber required in it than in the Plauen arch. Five-sixths cubic unit of timber was required for every 2 cubic units of masonry as shown below.

Taking the data from the summary of quantities—

Lagging and joists	88,000 ft. B. M. × 1	=	88,000 ft. B. M.
Trestle and Bracing	116,000 ft. B. M. × $\frac{70.25}{54.63}$	=	149,000 " "
			237,000

This gives an item of 237,000 ft. B. M. for a height of 70.25 ft. Now, in order to make a comparison with the Plauen centering, the vertical trestle item of 149,000 ft. B. M. should be reduced by the ratio $\frac{56.41}{70.25}$, making it 119,700 ft. B. M., which, with the item of 88,000 ft. B. M. for lagging, makes a total of 207,700 ft. B. M., or 640 cu. yds. timber for 1550 cu. yds. masonry, or 1 cu. unit of timber to each 2.42 cu. units of masonry, or five-sixths cu. unit of timber to each 2 cu. units of masonry.

Luxemburg Stone Arch Bridge.

In the centering of the Luxemburg Stone Arch Bridge, span 236.16 ft., rise 53.23 ft., illustrated in "Engineering News," Feb. 27, 1902, and Mar. 5, 1903, we find an arch of two ribs similar to that of Walnut Lane, but the radical difference is in the manner of forming the arch ring, which was to divide the depth of the arch into three rings and to erect and key one ring at a time, a method applicable to stone arches, but not so applicable to concrete arches. This method of erection manifestly allowed a lighter centering than otherwise, for the completion and keying up of the first ring made it assist the center in carrying the second, and the second ring when completed also assisted the center, together with the first ring, in carrying the third ring until its completion; therefore, as regards the strength of the center it appears fair to consider it as being built with sufficient strength to support two rings until the final keying of the second ring; the amount of

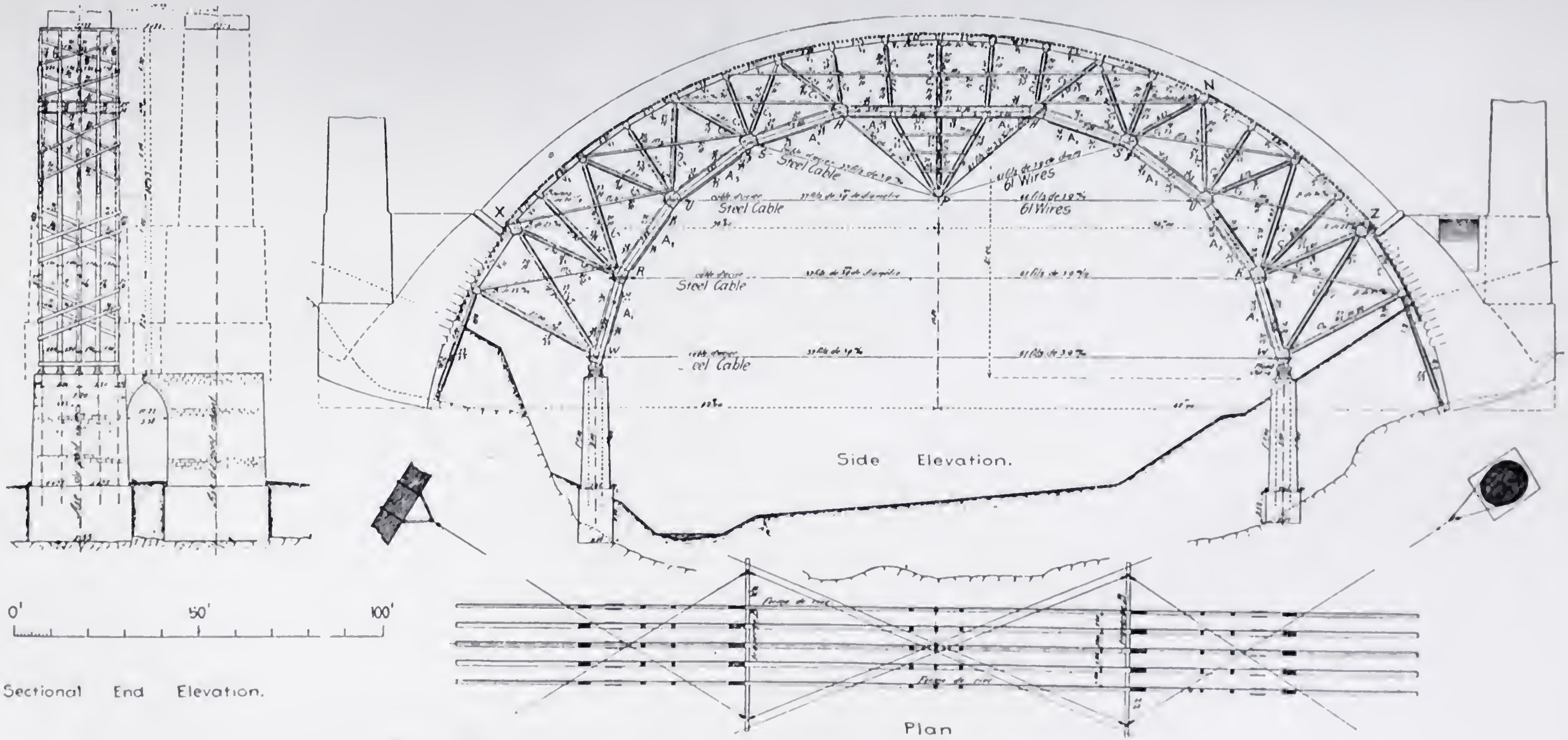


FIG. 16.—CENTERING FOR THE LUXEMBURG STONE ARCH BRIDGE.

masonry therefore carried by the center being two-thirds of the whole complete arch.

In order to effect a comparison between the Luxemburg and Walnut Lane centerings it was thought that means could be obtained by evaluating the summary of quantities in each case according to the quality of work and material, and thus obtain a comparative ratio by means of the total values for the amount of masonry carried; this is shown below:

Luxemburg:

Timber	145,000 ft. B. M.	@ $80.00	$11,600
Metal	157,000 lbs.	.06	9,420
Masonry	480 c.y.	7.50	3,600
			$24,620

In one arch rib 1110 c.y. masonry.

Walnut Lane:

Timber	340,000 ft. B. M.	@ $65.00	$22,100
Metal	265,000 lbs.	.04	10,600
Masonry	1,000 c.y.	10.00	10,000
			$42,700

In one arch rib 1550 c.y. masonry.

If we assume that the Luxemburg centering carried two rings until final keying, which would mean two-thirds of the total arch rib, then to carry the three rings would be 50 per cent. more; therefore we have

$24,620 + $12,310 = $36,930 for 2,220 c.y. masonry = $16.65 per c.y. masonry.

And for the Walnut Lane centering we have

$42,700 for 3,100 c.y. masonry = $13.80 per c.y. masonry.

Or the centering of the type of Walnut Lane costs five-sixths of the cost of centering of the type of Luxemburg; and in this connection it is well to note that the value of the above ratio obtained will not be appreciably changed by using other comparative units of value for work and materials than those assumed above.

PAPER No. 1057.

SAND—ITS USE AND APPLICATION IN THE VARIOUS INDUSTRIES AND PROCESSES.

W. S. REED.

(Visitor.)

Read May 16, 1908.

SAND is an aggregation of loose incoherent grains, usually of a crystalline structure, derived from the disintegration of rocks and other mineral matter, or produced by the grinding of sandstone, scoriæ, slag, cinder, or burnt clay. It is called silicious, argillaceous, or calcareous, etc., according to the character of the rock or other material from which it is derived or produced.

Sand is a vehicle, tool, or instrument by which we make application or utilize certain natural processes, chemical actions, or other physical forces and the laws controlling them. Its wide distribution over the entire surface of the earth and its great abundance, as water or the nitrogen of the air, would indicate that nature had anticipated man's needs, development, and advancement in the application of her varied forces and processes. Sand is in a sense a bridge or link between solid matter and liquid matter; the same as moisture or vapor might be spoken of as a bridge or link between liquids and gases. Sand partakes of the nature of a liquid because of its fluidity, that is, its particles moving readily in any direction like the molecules of a liquid, and yet at the same time its individual particles are solid matter. It is for the reason of this adaptability that it renders itself so conveniently to a multitude of processes in the various industries and arts. Some of its many uses are iron, steel, brass, and aluminum casting, tube welding, copper smelting, cores, furnace bottoms, ladle linings, cleaning of castings and iron plates by the sand blast instead of pickling, file finishing, file sharpening, fire bricks, ordinary clay bricks, sand-lime bricks, artificial stone, concrete blocks, manufacture of glass, glass polishing and etching, enamelling sanitary ware (iron), manufacture of pottery, glazes, terra cotta, stone sur-

faced roofing, tiles, patent imitation slate roofing, stove linings, fire-proofing, placing sand for the baking of biscuit ware, terra cotta, and some kinds of emery wheels, manufacture of crucibles, carborundum, gas mantles, sand-paper, dynamite, manufacture of wine, sand belts for spokes and hubs, engine sand for tracks, stone sawing and polishing, cement and lime mortar, cement finishing, plastering, railroad ballast, cleaning architectural and structural iron work, renovating the fronts of buildings, paving, asphalt work, manufacture of sand cement, distributing pressure in soft soils, manufacture of the silicate of soda, filler in pigments, paints, wood filler, sealing wax, vulcanized rubber, soaps, manufacture of phosphorus for match-heads, paper filler, filtering oils, acids, whisky, filtration and purification of water supplies, sewage disposal beds, and as a filler or adulterant in many other things.

The subjects of Water Purification, Sewage Disposal, Concrete and the Sand Blast have been selected for special description in this paper.

Physical and Chemical Properties of Sand and Gravel as Used in Filtration.

Upon both the physical and chemical properties of a sand depends its adaptability for filtration. Results in sewage purification which are obtained upon a sand and gravelly soil in one part of the country may be absolutely impossible upon the soils of some other section. So the successful purification of water by filtration depends largely upon securing a thoroughly suitable material.

Chemical Properties.

The sand which seems best adapted for filtration purposes is a quartzose sand, the silica content of which, calculated as SiO_2, should be not less than 96.0 per cent., and the lime and magnesia taken together and calculated as carbonates should be not more than 1.0 per cent.

Physical Properties.

The sand should be a hard material that will not disintegrate, the friable rock sands being unfitted for the purposes of filtration. The grain of both the sand and gravel should be round—in the case of the gravel, for the reason that it presents a more compacted surface, preventing the sand placed on top of the gravel from working down

and through it into the strainers of the filter. The advantages of a round-grained sand are that in such a material the percentage of voids can be calculated with greater accuracy and the working of the filter will be much more uniform over its entire surface, because the smaller particles will be found to be much more uniformly distributed in the interstices between the larger grains than is the case in a sharp sand. A round-grained sand in a mechanical filter will part more readily with its accumulation of sediment in the washing of the filter, than a sharp-grained sand will, which being the case is some saving in the cost of operation. The specific gravity of the sand for slow sand filtration should be not less than 2.63 and not greater than this for mechanical filters. It has come within the writer's experience that sands of greater specific gravity than 2.63 will not lift when the reversed current is applied for the purpose of washing the sand in a mechanical filter. The specific gravity of the gravel should not be less than 2.65, as lighter material will lift and whirl upward during the washing and become mixed with the sand. This also applies to flat or laminated particles in the gravel.

Size of Grain.

Upon the size of the sand grain largely depends the efficiency of the filter, and to a certain extent its cost of operation. For slow sand filtration the effective size of sand grain will average 0.30 to 0.40 mm. and the uniformity co-efficient from 1.50 to 1.80.

In mechanical filters the size of grain is somewhat larger, being an average of 0.50 mm. and a uniformity co-efficient as near unity as possible. A greater uniformity in size of sand grains is required in mechanical filtration, for the reason that in washing the filters the sand has tendency to separate itself into its different sizes and collect in vertical strata, with the result that when the filter is put into operation again it will filter more rapidly through the coarse strata, with a corresponding reduction in its efficiency. This also applies to the placing of sand in slow sand filter beds, where a greater uniformity co-efficient is allowed. It is important that the sizes be thoroughly mixed so that stratification will not occur in the sand beds and cause sub-clogging. This is especially important in regard to sand that has been removed from the filter for washing, as it has tendency to separate into different sizes during the washing, and should be thoroughly mixed before being replaced. It is also important that the sand beds be not stepped upon, as the sand will be more compacted in such spots

and cause unequal rates of flow, with a tendency of a more rapid and greater volume of flow through the less compacted sand, with a liability to cut channel ways and let impurities through. This also applies in the making of a sand joint against vertical walls or supports which should be stepped, for otherwise unfiltered water will find its way into the filtered effluent and thus show a reduction in efficiency of the sand.

Washing and Drying of Sand.

All sand and gravel used in filtration should be washed absolutely free from all loam clay or other impurities. The grading or separating of the sand into its various grades is usually accomplished during the washing process and is known as wet grading. The close separations required for sand used in mechanical filtration can not be accomplished by the wet process, and after washing, it is necessary to dry the sand in rotary kilns and separate it dry. Sand for slow sand filtration can be graded by the wet process entirely satisfactorily and should not be kiln dried, as the drying renders the sand sterile, destroying the useful fresh-water bacteria needed in the purification of the effluent in its final passage through the sand. This objection does not apply to such an extent to sand for mechanical filters, as the use of a coagulant in treating the water somewhat offsets this deficiency.

The sand should not contain mica or any appreciable quantity of laminated particles. Sand for slow sand filtration should not contain a greater quantity of fine sand than two-tenths of one per cent. of the size as 0.20 mm. or No. 80 mesh of a test screen.

Action of a Sand in a Filter.

The action of sand in a filter is entirely mechanical. It is that of a controlled strainer in which the depth and fineness of the sand govern the rapidity of its action. The water passes around the larger grains, which become coated with a film of gelatine-like matter, and between the smaller ones occupying the interstices, and there has been adopted from the series of experiments made at the Lawrence Station, Mass., the formula for calculating and making a mechanical analysis of sands, that will be described hereafter.

In addition to the sand acting as a strainer, it serves as a convenient medium for the action of the nitrifying bacteria, and as a container for the air supplying the oxygen, in the further purification of the already strained effluent, by the removal of organic and other impuri-

ties in solution. There seems to be some reason to suspect that by some further and more obscure action the last result of the nitrifying organisms in the production of inorganic salts of nitrogen is entirely eliminated from the water.

Frictional Resistance in Sand.

The passage of water through sands and soils is affected by temperature, the frictional resistance of the sand being increased with a lower temperature. The frictional resistance of the surface layer of the sands is very often greater than that of all the sand below the surface, and also for some inscrutable reason sands containing a larger percentage of alumina or iron in combination show this same effect.

The Mechanical Analysis of Sands.

The effective size of any sand is that size of grain of which 10 per cent. by weight of its particles are smaller than itself. The size so calculated is always referred to when speaking of the size of grain for filtration, and hereinafter referred to in connection with concrete sands. The uniformity co-efficient is the term used to designate the ratio of the size of grain which has 60 per cent. of the material finer than itself to the size which is 10 per cent. finer than itself. This finer 10 per cent. of the sand, the effective size, has been found to measure quite closely the work which the sand can do. The figures for a mechanical analysis of any sand are obtained by weighing a quantity of the sand, preferably 100 grams, and separating it into its different sizes by the use of standardized sieves. These sieves should be of the same diameter, at least six inches, with metal rims two inches in depth, their bottom so constructed that they will nest within each other, making a close joint, the bottoms covered with standard wire cloth.

As no two pieces of wire cloth appear ever to be woven exactly the same, it is necessary to have the sieves standardized, or in other words, have the openings accurately measured. This may be done in either of several ways. It may be measured with the aid of the microscope using a micrometer eye-piece, or the cloth may be photographed and enlarged, the magnification calculated and the openings measured on the photograph, or the size of the opening may be calculated from the size of grain which will last pass the sieve after a long and continuous shaking, when a small portion of the sand last passing may be weighed and the volume of a particle determined from the weight divided by the specific gravity and from this quotient the

diameter calculated. This diameter is taken as the size of the opening through which it passed. For convenience the size of each particle is considered to be the diameter of a sphere of equal volume. Taking the weighed portion of the sand and placing it in the top one of the nested sieves (the 100 grams previously mentioned), using as many sieves as there are separations required, agitating the sieves either in a mechanical shaker or by hand, at least 200 shakes, and then weighing each portion retained on each sieve, that portion retained being considered the same size as the opening of the sieve immediately above, or coarser than the one on which the portion is retained. Each portion is then weighed separately, starting with the finest portion from the pan used at the bottom of the nest of sieves. In plotting these weights as the percentages of the different sizes on a diagram, the sizes of the particles are represented by the ordinates and the percentages by weight by the abscissas. The portion in the pan, that passing the finest sieve used, having been weighed and its percentage marked, then the portion from the next sieve is placed in the scale with the first portion and both weighed together and this percentage marked, and so on, taking each next coarser portion until the whole 100 grams is in the scales, which equals 100 per cent. of the sample. The diagram as recommended by Mr. Allan Hazen as the one best representing the determined results is one in which the ordinates represent the sizes of the separations of the sieves in millimeters, and are logarithmic all the width of the scale. The percentages by weight represented by the abscissas are logarithmic as far as the 30 per cent. line, from which point the arithmetical scale is used to the 100 per cent. line, the constant differential being exactly equal to the differential of the logarithmic scale at the 30 per cent. line. The writer uses a scale which is entirely logarithmic both ways, as being more convenient. This diagram was made up by using the scale on the A side of a 10-inch slide rule for both ordinates and abscissas, and reducing it to one-fourth of its size by having it photographed down, from which a plate for printing was made. This made a very convenient size of diagram for mailing, about letter-sheet size. By using this diagram in conjunction with a ten-inch slide rule and a pair of bisecting dividers, the points may be picked off on the diagram very rapidly and accurately, as the quantities may be taken off from the A side of the slide rule by the longer legs of the dividers, and then picked off on the diagram with the shorter legs of the dividers, which equals exactly one-half the quantity taken from the rule. The writer

recommends this form of diagram as being much more convenient than the ordinary cross-section paper or Mr. Hazen's diagram.

Method for Determining Cleanness of Sand.

The most convenient and a sufficiently accurate method for determining the cleanness of any given sand is by the use of the silica standards. The writer had twenty-five glass tubes made, flat bottom, nine inches in length by one inch in diameter; two of these were fitted with ground-glass stoppers and the remaining twenty-three had their tops drawn out into thin tubes which, after receiving contents, might be permanently sealed by fusion over flame of blast lamp. In one of these tubes was placed distilled water, marking it No. 0. The two tubes with the glass stoppers were made for the purpose of placing samples in to be tested, distilled water being used in which to agitate the sample. These standards are prepared as follows: diatomaceous earth, as pure as may be obtained, is washed with water to free it from any soluble salts, and ignited to remove organic matter. The perfectly white earth thus obtained is then treated with warm hydrochloric acid (1 : 1), after which it is washed with distilled water by successive decantations until free from the acid. The material now composed of practically pure diatom frustules is then ground in an agate mortar to an impalpable powder and again shaken with distilled water; any coarse particles that may be present are easily separated from the fine particles by sedimentation and decantation. The fine material is then allowed to settle, separated from the water, dried at 100° C., cooled in a desiccator and placed in a stoppered bottle. Material thus prepared for use consists of particles of silica that are about 0.001 mm. in diameter and uniform in size. The stock mixture is made by adding 0.5 gram of the diatomaceous earth to 500 c.c. of distilled water. This is put into a liter bottle to give room for violent agitation before measured quantities of it are withdrawn. The mixture contains 1 gram of pure silica per liter, or 1000 parts per million. This is absolutely unacted upon by either distilled water or the platinum-cobalt color standard, and when well shaken will always give the same turbidity. From this stock solution standards of different turbidities may be made up to suit one's convenience. It is well to have under the glass tubes a black surface that extends backward about one foot, rising at an angle of about 30 degrees. This enables the observer to distinguish the particles in suspension, to judge the amount of light they cut out, and to estimate the turbidities

even though the particles vary greatly in size. The black surface may be changed to one with black lines on a white ground, thus eliminating the effects of color. When the sample to be examined exceeds the turbidity of the highest standard, the solution containing the suspended matter may be diluted down until a comparison may be made and turbidity calculated according to the amount of dilution.

The Use of Sand in Sewage Disposal Beds.

Sand required for this purpose should possess all the characteristics, both physical and chemical, required for water filtration. In a mechanical analysis of these sands a somewhat greater latitude is allowed in regard to the effective size of the grain and uniformity co-efficient. A typical specification reads as follows: "Sand for filling the secondary filter-beds must have an effective size of not less than 0.25 mm. and a uniformity co-efficient of not more than 4.0." Sand of this description free from all loam, clay, or other organic impurities, may be obtained from many natural beds of sand, some of the wind-blown dune sands of the sea-coast being especially adaptable for this purpose. The dune sands to which the writer has reference are quite different both as to size of grain and chemical composition from the ordinary beach sands found at Atlantic City and other seaside resorts. Over the joints of the underdrains in sewage disposal beds, clean washed gravel is placed to prevent the sand from working down through the joints into the drains. The action of the sand in a sewage disposal bed is purely mechanical. The ability of a sand to purify sewage, and also the treatment it requires for the best results, bear a very close relation to its mechanical composition, size of grain and thickness of bed regulating the rapidity of the flow through the sand. It also acts as a container for the several species of nitrifying bacteria and the air which supplies the oxygen during the process of nitrification, one species of the bacteria working in the dark in the interior of the bed and being able to survive with a scant supply of oxygen; the other species working in the light on or near the surface of the bed and requiring a plentiful supply of oxygen. These beds are worked intermittently, being allowed to rest for considerable periods of time. After such a rest, if the sand be examined, it will be found to be absolutely clean and as pure as when originally placed in the beds, the nitrifying bacteria all being destroyed because of lack of food. It will thus be seen that, as stated in a previous part of this paper, sand is the most effective and convenient medium or vehicle for applying

the process described. These sand filters as applied to sewage disposal are effective, economical, cleanly, and sightly. If properly handled, the effluent coming from them is safe to drink, and there will be no odor, nor any accumulation of foul matter on their surface. They produce no bad effects on the neighborhood, and, in fact, during a bad epidemic of cholera in Paris, not a single case was developed amongst the employees who cultivated the irrigation farms which disposed of the sewage from that city.

Sand as Used in the Sand Blast.

The sand blast apparatus has become one of the important adjuncts of the iron and steel foundry in the cleaning of castings. It does the work much more effectively, economically, and in less time than the old method of the scratch brush and tumbling barrel or rumbler. In the old method the more prominent projections of a casting were more thoroughly cleaned than the smaller and more intricate parts of the pattern, and the sharp or more prominent parts of the casting were liable to become chipped and small castings broken. It also has the advantage of giving an even color to the casting, thus more readily showing up any defects. It presents a better surface for painting and has the advantage of removing all the sand adhering to the surface of the casting from the mold, presenting a much more easily worked piece, when necessary for machining any part, especially parts cast against cores. This freedom from all sand is an important matter in the case of malleable work, as the presence of any sand in the casting greatly interferes with the annealing process. The use of the sand blast in cleaning architectural or structural iron work is one of the most effective methods that can be employed where paint is to be applied, as it presents a raw surface or quick of the metal, so that the paint can enter readily into the pores. It is economical in the fact that iron work so cleaned will stand much longer without repainting under the most severe tests—instance the iron girders of a bridge crossing over the subway leading into the New York Central Railway Station, subject to the gases of many passing locomotives, a most severe test. In so using the sand blast the painter should work beside the sand blast operator, as oxidation of the metal commences immediately and is the cause of paint scaling. The sand blast is effective in renovating the fronts of buildings, especially so in the case of stone structures which have been damaged by smoke stains from fires, etc. The hardest materials are the most rapidly attacked, while soft or elastic

substances, like rubber, blotting paper, and even the human skin, are either not at all or but slightly affected. One more important use of the sand blast is in the cleaning of iron plates to be used in sanitary ware, which is to receive a coat of enamel. The enamel adheres much better to a surface cleaned with the sand blast than one cleaned by the old slow process of pickling. In operating the sand blast in foundry work it has been found that a large volume of air at low pressure, 15 lbs. to the square inch, is far more economical than a small volume at high pressure. The sand blast requires a perfectly clean sand, preferably kiln dried and shipped dry in box cars. It must be a quartz sand, but of sedimentary origin, that is, a sand that has been derived from sedimentary rocks. Such a sand has been found, from the writer's experience, to be tougher than the sand from original crystalline quartz rocks. While the latter is harder it is much more brittle and will not last as long in the machine. Glass is very hard, but is of no use whatever in the sand blast, as it is too brittle, as are all sands of a highly developed crystalline structure. The sands for this purpose are supplied in four sizes of separations according to the character of the castings. A No. 1 sand, about 1.0 mm. in size of grain, is used for small castings and stove work. No. 2 sand, about 1.5 mm. in size, is used for medium sized castings and plate work. No. 3 sand, about 2.00 mm. in size, is used for large steel castings. Some few foundries use a gravel the size of a large pea. The specific gravity of this sand should be as high as possible—2.63 to 2.65 plus, as the sand acts as a hammer; it is essentially an impact blow rather than abrasion, notwithstanding the popular impression to the contrary.

Sand for Concrete.

The writer does not wish to be understood to be posing as an expert or in any way encroaching on the province of the concrete engineer. Where there is such diversity of opinion among eminent engineers and scientists, the humble sandman can not hope to settle the differences, but simply wishes to add, with all humility, some of his observations, perhaps observations somewhat more trained than the ordinary vender and miner of sand. It is perhaps this observation of some of the little, ordinary things that are so often and easily overlooked because of the lack of opportunity for observing them, that cause so many of the results and deductions from laboratory tests and experiments to fail in their development in the larger field of practice. Then, too,

the sandman comes into contact with such a wide field in the use of sand that he often gains a knowledge from application of the material in one industry that gives him valuable information that will help elucidate intricate problems in another line of work, and which would perhaps never occur to one following a single line of application only. One of the first things to be considered in taking up the subject of concrete sand is the wording of the specifications for the material. As usually worded, they simply state "a sharp, clean, coarse sand," when, as a matter of fact, the word rough would be the proper word to use to express this one physical characteristic of the sand. The word sharp has such a psychological effect on the mind that the producer of sand is liable to supply and the engineer to accept a sand not always well suited to his purpose. Round-grained sands are not sharp, but they may be rough, like a satin finish on a metallic surface, and be pitted with small cavities, presenting a very much more satisfactory surface than the smooth fracture of a sharp sand, as the feldspathic sands derived from granite or granitoid rocks. Referring to the word clean, free from all loam, etc.—as a matter of fact loamy sands will make as good if not better concrete than the clean sands will, showing a much greater percentage of strength in the tensile tests, and, as one writer states, "a strength amounting 20 per cent. greater." The writer in conversation with a prominent contractor in Philadelphia had occasion to discuss this matter, when the gentleman informed him of an instance where, in the course of alterations to a portion of the Reading Terminal structure, he found it necessary to blast out a part of the masonry work in order to remove it, so firm had it become in the course of a few years. In that work, which he built originally, he had used Jersey gravel, which we all know carries a large percentage of loam.

Influence of the Size, Shape, and Chemical Composition of the Sand Grains upon the Ultimate Strength, Heat Conductivity, Permeability, Cost of Production, etc., of the Concrete.

It is commonplace to make the statement that fine sand does not make the strongest concrete; that it contains a greater percentage of voids than coarse sand, has a greater surface to cover with the cement, and it is with greater difficulty and considerably more labor that the interstices are filled with cement. So many careful tests and experiments have been conducted by competent men the world over, and

the literature on the subject has now become so general and voluminous, that it does not seem necessary to refer to this particular item to any greater extent. Fine sand, in addition to having a greater percentage of voids, will, and does for that reason, increase in bulk to a much greater extent than coarse or mixed sands, according to the amount of capillary moisture contained up to the point of complete saturation. The word capillary is used as opposed to hygroscopic moisture, as will be mentioned hereafter. Fine sand should not be used for sea-water construction under any consideration. There appears to be some evidence coming from several different and independent sets and sources of experiments and experimenters, that the curve for tensile strength rises with sands finer than a 140 mesh, but as such sands are so rarely found in natural beds, this matter need not be considered further, as it is the writer's intention to deal only with materials as found in practice and that can be used and prepared under practical working conditions.

A sand which the writer has handled in considerable quantity and which has been approved of by the U. S. Army Engineers for sea-wall construction, etc., as well as used in the construction of concrete buildings, railroad bridge piers and abutments, is a quartzose sand having rounded grains of mixed sizes washed thoroughly clean. The sand showed upon mechanical analysis an effective size of 1.00 mm. and a uniformity co-efficient of 2.00. This sand more readily agrees with the numerous comparative tests showing the greatest ultimate strength of concrete made by numerous experimenters. It also agrees in many respects, except as to its very coarsest particles, with Feret's granulometric composition of various proportions of sizes of sand grains. Naturally such a sand will contain the smallest percentage of voids, requiring less cement, and giving a much greater density to the aggregate at a less expense for the cost of cement. As is well known, round-grain sands contain a smaller percentage of voids than the sharp sands, and when rammed will form a much denser mass and with less frictional resistance in the compacting. This question of the friction of sand was taken up experimentally by Messrs. More & Harris Tabor in connection with its relations to machine molding some years back. Their experiments showed that in a 4 by 4 in. box with $2\frac{1}{2}$ ins. of loose sand placed in it in order to compress this sand to $1\frac{11}{16}$ ins. and give a density equal to 10 lbs. pressure to the square inch on the under side, it required a pressure of $12\frac{1}{2}$ lbs. on top of the sand. With 5 ins. loose sand it required $17\frac{1}{2}$ lbs. pressure,

$7\frac{1}{2}$ ins. of sand required 34 lbs. pressure, while 10 ins. required 42 lbs. pressure. When these same depths of sand were placed in a 6 by 6 in. box, it required only $11\frac{1}{2}$ lbs., with $2\frac{1}{2}$ ins. loose sand, and 26 lbs. with 10 ins. of loose sand, which is 16 lbs. less than was required under precisely the same condition with a 4 by 4 in. box. It seems therefore that a point well worth considering is the selection of sand which will give the least frictional resistance to compacting. One objection to a sharp-grained sand of irregular outlines is that it not only contains more void space, but gives greater resistance to compacting, but even in the smaller particles of such a sand there is a tendency to arch, as with broken stone, and as mentioned by Mr. T. Dunkin Paret, in his article on "Interstitial Space," "Journal of the Franklin Institute," August, 1895. In a series of experiments conducted by the German government for testing the standard sands of all the nations, in relation to their use in Portland cement testing, it appeared that while the sharp crushed quartz standard sand of America gave satisfactory results in regard to tensile strength, and showed up somewhat better than the round-grained sands of other countries did when the proportion of sand to cement was increased above that of 1 : 3, contrary to the usually accepted data and as mentioned by Mr. Johnson in his book on "The Materials of Construction," the compressive strength of the sharp quartz sands was much less; this is further borne out by comparing the crushing strength of Red Potsdam Sandstone of New York, which is 42,804 lbs. per square inch, with a brown Triassic sandstone from Portland, Conn., the crushing strength of which is only 13,000 lbs. per square inch. If one compares these two structures under the microscope, it will be noticed that the Potsdam stone is composed of more rounded grains than the stone from Portland, Conn.

Fire Tests of Sands.

The writer, several years ago, had a series of tests made on a number of sands by Prof. Heinrich Ries, at the laboratories of Cornell University, to determine their fusibility, and with but one exception all the sands tested of somewhat different chemical composition, but all silicious, fused at 3254° Fahr. In considering the fire-resisting properties of concrete it should be borne in mind that the co-efficient of expansion of quartz is very high in comparison with some other materials, and that quartz has a peculiarity of expanding less in one direction than in another direction perpendicular to it. This compara-

tively high unequal expansion of quartz undoubtedly has a tendency to cause disintegration of the concrete under the action of heat. The expansion of silica fire brick in iron furnaces is too well known to need any description. It would seem that this question is one of great enough importance for the concrete engineer to look into in the erection of fire-proof structures, as it has been fairly demonstrated that limestone aggregate will calcine and become punky when subjected to intense heat. It would seem from this that the best fire-proof construction concrete that could be erected would be composed of trap rock and trap rock screening for an aggregate, and that all limestone, silica gravel, and silica sand should be avoided where the construction is ever likely to be exposed to great heat. On the other hand, silica gravel and sand make a superior structure in aggregates not likely to be exposed to heat. Many structures which have been standing for years were made of gravel concrete exclusively, as the foundation for both towers of the Brooklyn Bridge, in which the concrete was made of one part Rosendale cement, two parts sand, and four clean gravel by measurement, and these foundations have carried their load without any appreciable settlement since 1872. Gravel concrete was used twenty years ago in constructing the Prospect Park Reservoir in Brooklyn, and it is in perfect condition today. In 1871 Mr. F. Hopkinson Smith used gravel mixed with broken stone in constructing the Race Rock Lighthouse in Long Island Sound. Mr. Smith said he used gravel in mixing large masses of concrete because its rounded surfaces packed more closely in the interstices of the broken stone and there was no possibility of arching, as sometimes occurs when broken stone is used alone, even when the presumption is that the concrete has been thoroughly rammed. This difficult piece of work has to withstand the thrust of immense fields of floating ice. In the old Croton Aqueduct, commenced in 1838, the concrete is made largely of gravel and pebbles and proves solid and water-tight today. The sea wall at Staten Island is composed of one part of Portland cement, two parts of clean sharp sand, three parts pebbles, and four parts stone, broken to pass a two-inch ring.

Wet and Dry Sand.

There is great liability to error in calculating the proportions of sand and cement upon a job of concrete construction, because nearly all of the laboratory tests made are made with dry sand, while in actual practice it is obviously necessary to use a damp or moist sand; there-

fore in determining the proportions this fact should be borne in mind—that wet sand shovelled in loosely weighs less to the cubic foot than dry sand, and that wet sand may show a difference of 6 per cent. greater bulk than the same quantity of sand dried. This is especially so if the sand is anywhere near uniformly graded, and so, on the other hand, sand that is settled under water will show a decrease of nearly 6 per cent. in bulk under the same sand when dry. For this reason that method of determining the percentage of voids in a given sand by dropping it grain by grain into a vessel filled with water and noting the quantity of water displaced, and calculating therefrom the percentage of voids, is very unreliable, and would show great discrepancy with the actual conditions in either a dry or moist sand.

Chemical Composition of Sand.

Under this heading the different minerals which compose the aggregate of various natural sand beds are considered, their chemical composition being associated with their mineralogical names; their resulting peculiarities of crystalline structure from different chemical compositions producing different kinds of fracture and cleavage, presenting a smooth and glassy surface or a rough and uneven surface.

Mica is a constituent of granite, granitoid and schistose rocks, and is frequently found in excessive quantities in sands derived from rocks of the above description, and when present to the extent of 2 per cent. or over, it would make such a sand prohibitive for use in cement mortar, as it prevents the cement from setting. That certain chemical reactions eventually take place as a structure of cement or lime mortar ages has long been a known fact, as an examination of mortar from very old buildings which have been torn down or demolished shows that in lime mortar silicate of lime is gradually formed as the air penetrates into the interior of the mass, making a very dense structure, and frequently this is so hard and tenacious that an ordinary clay brick will break before the mortar will leave its surface. There is no reason to suppose that this same action does not take place in cement mortar, especially where it is subjected to various conditions of heat and moisture, which necessarily accelerate chemical reaction. Often the simple presence of some element has a tendency to influence in an inscrutable manner chemical action, and yet they are not acted upon themselves, as instanced black oxide of manganese present with chlorate of potash retards the chemical action in the potash

when heated, in giving off oxygen. Again the metal aluminum added to steel will, instead of increasing the bulk of the mass by the addition, actually reduce it, the aluminum seeming to absorb a larger quantity of the steel than it displaces. There seems to be a wide field for study in cement mortar for the chemical engineer. The strength of cement mortar is undoubtedly increased by thorough tamping of it, as the strength of metal is increased by hammering its particles closer together.

The Effect of Clay and Loam on Cement Mortar.

There is probably no other feature in regard to sand which has been more fully discussed and over which there seems to be such a diversity of opinion. The writer's attention was first drawn to this matter by a paper read at the National Cement Association Meeting held in Indianapolis in 1905. The paper was written by Mr. J. C. Hain of Chicago. Mr. Hain was employed by the Chicago, Milwaukee & St. Paul Railroad Co., in the bridge department, where he had charge of the masonry construction. This railway has 7000 miles of track, along which, for their own use, the company owned and operated a number of sand pits. All their sewers, many of their bridges, bridge piers, and abutments, are constructed of concrete. They maintain a well-equipped laboratory for thorough and careful tests, and a series of tests with various sands in connection with cement were held over a period of three years. These tests for this reason are much more satisfactory than the brief seven day, twenty-eight day, and ninety day tests of some other experimenters. Instances arose where it was necessary to conduct large operations of concrete construction in which the only available sand near the work contained either clay or loam, so that it became a question of using the sand near at hand or hauling sand long distances—as much as 100 miles in some instances— from pits where apparently more suitable sand was to be had. The result proved, much to the surprise of every one concerned, that the sand containing as much as 15 per cent. clay made a stronger cement than the standard sand used in the laboratory, which was a clean sharp sand of a mixed grade. A condition arose in building the concrete highway bridge at the Golden Gate, Yellowstone National Park, in which the only available sand was a sand containing from 3 to 7 per cent. by volume of alkaline earth. Upon the completion of the work, briquettes made of the cement and earthy material as used showed a higher tensile strength than briquettes from the same material after washing. This bridge was constructed in 1900 and has now well

withstood for several years the extremes of climate of our National Park, showing that the earthy material has not affected the weathering properties of the concrete there. Prof. C. E. Sherman conducted a series of experiments covering this phase of the question from May, 1902, to May, 1903, in which a 15 per cent. mixture of clay and loam in the sand proved to be stronger at the end of one year in eight cases out of twelve. Mr. C. E. Clark, in "The Transactions of the American Society of Civil Engineers," vol. xiv, reported that 10 per cent. of loam used with clean sand and Rosendale cement did not decrease the strength after six months or a year. He found that some 350 briquettes of Portland cement were not weakened by clay in moderate quantities, nor their weathering qualities impaired after 2½ years. In a series of tests made in 1877 at the German Harbor of Wilhelmshaven, sand not washed gave better results than the same sand did when sifted and washed. Instances of this character might be multiplied indefinitely, but it appears to the writer that clay or loam adds to the strength of cement mortar only when present in the sand as a mixture and not as a coating or film around the grain. The moisture in such a sand will be hygroscopic and such a sand will not have a tendency to stratification in the handling or shipment.

The writer has experienced on more than one occasion the tendency in dry sands of all the fine sand to work toward the bottom of the pile or bottom of the car in transportation, a tendency not observed in damp sand. Therefore in the working and use of damp sand a more even admixture of the various sizes of grains throughout the mass is maintained, and this may account in some measure for greater strength in sands containing clay or loam as a mixture. This specification is often met with—"sand used in mortar must be so coarse that the individual grains are plainly distinguishable to the naked eye as the sand is piled." When sand dries as piled, it will be found upon inspection that all the fine sand has worked down into the pile and only the coarse sands remain on the angle of repose. So in sampling a bank care should be taken never to take a sample from an old face, but cut into the bank if you would secure an average sample, and quartering it should be resorted to if a mechanical analysis is proposed. The so-called inert or impotent sands of the Orient appear to be sands very much of the character of molding sands used in our iron foundries. All these sands contain a greater or a less percentage of loam or clay. These inert or impotent sands take their name because they appear to have no power to expand or contract. They are practically incom-

pressible, and yet you could dig them out with your hand. In the Orient they build on this impotent sand without hesitation, as being next best to or practically as good as rock. It would appear that the ancient Egyptians understood the nature of this kind of sand, and when they could not get rock to build upon, they dug deep their foundations and filled them with this special sand, which they must have imported for this purpose, and then laid their buildings upon it. In his account of excavations south of Tanis, Petrie says, "at last a mass of sand was found with a vertical face, and this I at once recognized as the sand bed in the earth on which the walls of the temple had been founded."

In conclusion, an examination of the preceding data shows that fine sand makes a much weaker mortar than coarse sand, and that the best sand is that which has grains of several sizes, such that the smaller grains fit into the voids of the larger, the proportion of any particular size being only sufficient to fill the voids between the grains of the next larger size. The grains should be rounded, for they will show a less percentage of voids, of from 2 to 5 per cent.

There are many other interesting features of the subject which might be considered, such as the geological history, which would be a history of the formation of the earth's surface, the precipitation of the various chemical components under degrees of heat and superheated moisture absolutely incomprehensible to our present experiences, or the probable glacial origin of molding sands and their deposition in still waters might be written about, or the refractory properties of the high silica sands used in steel casting or furnace bottoms, their chemical compositions, latent heats, the various and intricate phenomena of the blast furnace as it affects the sands used in connection with its operation; the experiments in attempted rejuvenation of burnt-out molding sands, or a description of the physical and chemical properties necessary in glass sand, or sand used for enamelling sanitary ware, pottery, glazes, etc., each of which would require a paper in itself.

Paper No. 1058.

EXPERIENCE IN OPERATING DIESEL ENGINES.

JOHN S. HAUG.

(Junior Member.)

Read at meeting of Junior Section, May 11, 1908.

The Diesel engine is an internal combustion engine which utilizes as fuel crude petroleum or distillate without previous gasification. It has also been run successfully on water-gas tar, a by-product from the water-gas process of about 1.06 specific gravity and viscosity slightly more than ordinary fuel oil. The Diesel engine is essentially an oil engine, as compared with engines which burn distillate or crude oil by previously vaporizing it in an iron retort heated by the exhaust.

These latter engines are practically gas engines, and while they utilize distillate satisfactorily, a deposit of coke is left in the retort when using crude oil which must be cleaned out at rather frequent intervals. With the Diesel, however, there is no residue whatever, even from those fuels which contain suspended carbon, as does the water-gas tar before referred to. The exhaust is absolutely colorless. A sheet of white paper held over the exhaust will show no stain. This means that combustion is probably as nearly perfect as can be obtained.

The Diesel engine is distinctly a combustion engine as opposed to an explosion engine, in that there is little or no rise in pressure when the fuel is injected; in fact, what is aimed at, is an isothermal combustion, which, of course, would fall below the constant pressure line. It operates on the four-cycle plan as follows:

The first stroke is the suction stroke, and fills the cylinder with air at atmospheric temperature and pressure. This is constant for all loads. The second stroke compresses this air into the very small clearance of 7 per cent. of the volume swept through by the piston. As a certain amount of cooling from the water jacket takes place the compression falls somewhat below the adiabatic (the equation being

approximately $p\,v^{1.34} = K$), resulting in a pressure of 500 pounds per square inch, and a temperature of about 800° Fahr.

Just before the dead center the fuel valve starts to open and the fuel is injected in the form of a mist by air at a pressure of about 750 pounds per square inch. As the fuel valve is opened only very slightly, this injection does not take place at once, but lasts for about 10 per cent. of the stroke, resulting in a steady combustion. The temperature at the end of the combustion is about 1900° Fahr. at full load, but remains more nearly constant at light loads. This temperature is considerably lower than the explosion temperature of gas engines.

After the closing of the fuel valve the gases expand on the working stroke, the temperature falling. The equation for the expansion curve approximates $p\,v^{1.3} = K$. Just before the end of the stroke the exhaust valve opens. The fourth stroke expels the burnt gases. Over three times as much air is furnished as is necessary to support combustion.

It will be seen that one of the distinctive features of the engine is its high compression. A comparison of the full load indicator diagrams of the Diesel engine with 7 per cent. clearance and a gas engine using illuminating gas with about 27 per cent. clearance shows a compression pressure of 70 pounds, and an initial pressure of 260 pounds for the gas engine as against 500 compression and 530 initial for the Diesel engine, and an expansion of the burnt gases to 3.7 volumes for the gas engine as compared to 6.7 volumes for the Diesel engine. The mean effective pressures of the above cards are 66 pounds for the gas engine and 105 pounds for the Diesel engine. The reason this high compression can be obtained is that air alone is compressed. This makes pre-ignition impossible and does away with ignitors.

From this it will be seen that the Diesel engine has a considerably smaller cylinder volume than the gas engine, of equal power and the same number of revolutions per minute. This reacts favorably on the design, compensating to a considerable extent for the stronger construction necessitated by the high range of pressures in the cylinder, so that in weight the Diesel engine compares favorably with other internal combustion engines of the same speed and power. The weight, including fly-wheels, of the three-cylinder 16″ × 24″ American Diesel engine of 225 H. P. and 164 R. P. M. is 356 pounds per horse-power. The single cylinder 16 × 24 engine of 75 H. P. and 164 R. P. M. weighs 573 pounds per horse-power. The smallest three-cylinder engine built

by the American Diesel Engine Company is 12 × 18, of 120 H. P. at 220 R. P. M. and weighs 275 pounds per horse-power.

One would expect from an engine with such a high compression an unusually good economy, and the Diesel comes up to expectations in this respect. One of the tests published by the American Diesel Engine Company of a three-cylinder engine of 225 H. P. shows that at quarter load it consumed 15,100 B. T. U. per horse-power hour; at half, three-quarters, and full load it consumed 9590, 9130, and 9030, B. T. U. respectively; at about 16 per cent. overload it consumed 10,000 B. T. U. per horse-power hour. The full load consumption represents an absolute thermal efficiency of 28.1 per cent. All the above consumptions are based on the actual output in brake horse-power of the engine, and include the amount of heat expended in driving the compressor, which furnishes air for the injection of the fuel. At full load 840 B. T. U. per H. P. hour were expended in driving the compressor, making 8190 B. T. U. in main engine.

One of the most attractive features of the Diesel engine is the manner in which this economy is maintained at low loads, since most plants operate on light loads for a greater part of the time than on loads near the capacity of the machine. There are no "stand by" losses.

The Diesel engine is adapted for high as well as moderate speeds. An engine has been brought out by the Augsburg works in Germany, for marine work, of 300 horse-power at 400 R. P. M., weighing with all accessories 22,330 pounds, or about 74.5 pounds per H. P. They also show the characteristic low fuel consumption of the Diesel engine.

The fuel cost is, however, not the only cost of operation. The consumption of lubricating oil is also part of the expense of running. The American engine has an inclosed crank case with splash system of lubrication and an oil of flash-point of about 580° is used. The consumption of this oil for a three-cylinder 225 H. P. engine is about six gallons per day of twenty-four hours. This is the consumption obtained in the new Diesel engine plant at Station B of the Philadelphia gas works. One of the disadvantages of the inclosed crank case is that the crank shaft has to be packed to prevent the escape of oil. It is not always possible to keep this tight, especially in the case of our single-cylinder engines, where the fluctuations of pressure in the crank case are rather violent, in spite of a two-inch vapor pipe which is supposed to relieve this pressure. The crank case oil consumption of our single-cylinder (75 H. P.) engines at Station A of the Philadelphia gas works is about 2.5 gallons in twenty-four hours.

The item of repairs is also one of the expenses which must be considered. This in the case of the latest three-cylinder engines will compare favorably with the repairs of a steam plant, including boilers and accessories. The repairs on the single-cylinder engine are higher because the duty is more severe. A fact which is sometimes forgotten is that repairs on a machine that runs twenty-four hours a day will be over twice as much as those on a machine running ten or twelve hours a day.

The small attendance required is one of the strong points of an oil engine. It requires more care and attention to keep it in running condition than a steam engine does, but the boiler-room, with its firemen, water-tenders, and handling of coal and ashes is entirely eliminated, the net effect being a decreased attendance for the plant as a whole when compared with a steam plant. The average careful, intelligent steam engineer with proper training can run the Diesel engine successfully. In this point of attendance the oil engine also surpasses the gas engine, which must have a producer plant for economical operation in large sizes, if no cheap gas is obtainable.

As to reliability, the new plant at Station B, already referred to, has operated for several months successfully without interruption of service due to the engines. The plant consists of three, 225 H. P. 16 $\times$ 24 three-cylinder engines of 160 R. P. M., direct connected to 25-cycle alternators which operate in parallel. There are three three-stage air compressors, two of them motor-driven and the third steam-driven. These air compressors were built by the Norwalk Iron Works Co. and have been very satisfactory. One steam-driven air compressor is a necessity in a plant of this kind, if only as a safeguard against accident.

The Diesel engine plant at Station A, Philadelphia Gas Works, consists of two 16 $\times$ 24 single-cylinder engines of 75 H. P. each at 160 R. P. M., belted to a Wilbraham Green gas exhauster. There are two two-stage single-acting air compressors built by the American Diesel Engine Co. One of them is belted to one of the engines. The other is belt-driven by a small steam engine. In both plants there are four heavy steel bottles for each engine, 8 in. diameter by 4 ft. long, to act as air reservoirs in starting, etc. One of the engines at Station A had the remarkably long run of forty-eight days and thirteen hours without shut-down. The engine was in good condition when shut down, with the exception of a leak from the fuel valve packing. This shows what can be done in long runs. It is

probably unwise to let an engine run that long, because of the desirability of regular inspection.

In general appearance the American Diesel engine resembles somewhat the ordinary vertical gas engine, as it is single-acting, vertical, with inclosed crank case, inlet, exhaust, and jacket water piping. The valves are in the cylinder head in a projection on the side of the cylinder. The inlet, or air admission valve, is carried in a cage bolted to the head and is vertically over the exhaust valve, the inlet valve opening downward, while the exhaust valve opens upward, both valves being cam-operated. Neither the inlet nor exhaust valves are water-cooled, but are plain bell valves made of nickel steel and of about the same shape and size. The fuel valve, which consists of a 25 per cent. nickel steel needle $\frac{5}{8}$ inch diameter and about 12 inches long, is carried with the atomizer horizontally in the needle valve bracket which is bolted to the side of the cylinder head. The needle valve is closed by a heavy spring and opened horizontally by the thrust of a bell crank operated by a cam. The spray of fuel is injected into the combustion chamber in the cylinder head, across the space between the faces of the inlet and exhaust valves. The starting valve is also carried in a small cage bolted to the cylinder head and is opened vertically upward by a cam.

The cam shaft, driven by spur gearing from the crank shaft at half the speed of the latter, runs in the crank case, and carries four cams. The admission and exhaust cams are keyed solidly to the shaft, while the fuel and starting cams are mounted on a barrel driven by a feather key attached to the cam shaft by screws, allowing the barrel to be shifted along the shaft by a lever, in such a way that when the lever is thrown one way, the fuel cam alone engages its valve rod; and when the lever is thrown the other way, the starting cam alone engages its valve rod.

In starting, the engine is placed slightly past its upper center on the working stroke with the starting lever thrown over so the starting cam engages its valve. The starting valve will then be open. A charge of oil is then pumped up to the fuel valve by hand and the injection air pressure turned on. When all is ready, the stop valve on the compressed air line to the starting valve is opened and the engine starts off on its regular cycle, with the exception that on the working stroke a heavy charge of compressed air is let in instead of the regular fuel injection. After three working strokes—six revolutions—which are necessary to bring the engine to a high enough speed and temperature, the starting lever is thrown over to engage the fuel valve rod with its

cam, cutting out the starting valve, and a heavy charge of oil is ignited, the engine quickly coming up to speed. The fuel cam can be shifted slightly in a plane at right angles to the cam shaft to allow different settings of the valve for different oils. By lengthening the fuel valve rod the needle valve can also be made to open earlier and close later, and by shortening it to open later and close earlier. Thus there are two different adjustments.

The valves are five in number. The admission, exhaust, and fuel valves are used in the regular operation of the engine, and there are also a starting valve, actuated from the cam shaft, for starting the engine with compressed air, and a safety valve to relieve pressures above a certain point; roughly, in the neighborhood of 700 pounds per square inch. The seats of the valves are all in the head. The exhaust valve seat is in the head directly, while the other valve seats are in removable cages bolted to the head.

A distinctive feature is the process of the injection of fuel, which takes place through an atomizer constructed of two concentric tubes. The inner one fits the needle valve closely, and the space between the inner and outer tubes is filled with oil from a duct milled along the side. The compressed air enters along another duct through holes into the annular space containing the oil, and blows out with the oil when the needle valve opens through another set of holes at the outlet end of the atomizer.

The governor is driven by a bevel gear and pinion from the end of the cam shaft. The fuel pump plunger is driven by an eccentric sleeve on the end of the cam shaft, the sleeve being driven through a pin from the cam shaft. The method of governing is extremely simple and ingenious. The fuel pump suction valve is opened by a lever pressing down on the suction valve as the plunger goes up, the other end of the lever being attached to the plunger. The suction valve is closed by a spring. The fulcrum of the suction valve lever which is between the plunger and the suction valve is movable, and its position depends upon the position of the governor balls. Thus when the balls have risen to their highest point, due to an increase in speed of the engine, the movable fulcrum is depressed so that the suction valve is held open for all positions of the plunger, consequently no oil is delivered to the engine. When the speed drops the fulcrum rises and permits the valve to close. As soon as the suction valve has closed, and not until then, oil is forced up to the needle valve. It will be seen then that the lower the speed is, the earlier in the stroke of the fuel

pump plunger does the suction valve seat itself, and as the speed increases the suction valve begins to seat itself later.

The revolutions per minute remain remarkably steady. Of course, the variations in angular velocity per cycle are considerable in a single-cylinder engine, but in the triple-cylinder engine are not large enough to prevent working alternators in parallel, which is done in the plant at Station B, Philadelphia Gas Works, already referred to.

Causes of Trouble and Remedies.

The most serious cause of trouble in the Diesel engine, and in fact in any internal combustion engine, is loss of compression. This affects the engine in two ways: first, by reducing the temperature at the highest point of compression; and, second, by failing to give back to the fly-wheel all of the work absorbed from it on the compression stroke. The compression of air which is allowed to escape uselessly in leakage results, of course, in a direct loss of power, while the reduction of the temperature results in another loss, in that the combustion, which under proper working conditions should take place during the opening of the needle valve, is not completed until well after the valve is closed, causing a considerable loss of area in the upper part of the indicator diagram.

The immediate indication of the loss of compression is incomplete combustion, resulting in a smoky exhaust instead of a clear one. This necessitates increasing the pressure of the injection air, so that the fuel is injected in a state of finer subdivision. This will clear up the exhaust in all but the worst cases, but an extra load is thrown on the compressor and an increase in the oil consumption per unit of work is noticed. As the loss of compression goes on, the load the engine will carry without smoking decreases, and the oil consumption increases.

One of the first things to learn in operating the engine is that it should never be allowed to run with a smoky exhaust. As soon as the condition of the engine becomes such that it will not perform the duty expected of it without smoking, a thorough search should be made for the cause of the trouble. Perhaps the most frequent loss of compression is by leakage past the valves.

The exhaust valve is most frequently affected in this way, and it may be due to a poor seat, pitted by particles of carbon getting under the valve and forming depressions. The remedy for this is regrinding. This is done by putting oil and emery on the face of the valve and

rotating it with a brace and special bit while pressing it down on its seat. Sometimes the seat of the valve appears good, but leakage takes place because the valve assumes another position when working from that in which it was ground. When this is the case, the seat, instead of being clean all around, is bright on one side and dark on the other, the dark patch showing where the leakage has taken place. This is usually due to looseness in the exhaust valve guide, and the remedy for this is also regrinding more carefully. This looseness in the guide is often caused when grinding the valve, by oil and emery running down the stem and getting into the guide. This can be prevented by wrapping a cloth around the throat of the valve above the guide.

An exhaust valve is occasionally found with a V-shaped portion of the seat burned out. This is due to overheating caused by a leaky needle valve. This condition exists by itself, and also in conjunction with a cylinder head cracked in the exhaust valve seat. The leakage of hot gases concentrated at one point soon produces a local temperature equal to the fusing point of the metals, with the result that both valve and seat are burnt. We have repaired such valves by welding a piece of soft steel into the damaged edge of the valve and re-machining it. It is necessary to ream down the seat in the cylinder head, if it is damaged, until a good bearing all around is obtained. In case the cylinder head is cracked at that point a very good temporary repair can be made by drilling and tapping out the crack in the seat, and plugging it. The remainder of the crack can be drilled with one-quarter inch holes three-quarters of an inch apart to act as pouring gates for a cement composed of sal-ammoniac and iron borings. This should be allowed twelve hours to set. Cracks at this point in the cylinder head are usually caused by overheating from a leaky needle valve, but sometimes are due to a poor casting containing internal strains. We have permanently repaired a cracked head by rebushing the exhaust valve seat with a cast-iron ring, and it seems to stand very well. A leaky needle valve will also cause the exhaust valve to dish, being deflected by the pressure while in an overheated state.

Trouble with the admission valve is less frequent, since it is kept relatively cool and clean by the entering air. It will occasionally foul, however, especially if the needle valve leaks, or if the engine is allowed to smoke.

Leakage past the admission valve is easy to detect, since it can always be heard, which is usually not the case with the exhaust valve. The

admission valve cage which contains the admission valve is bolted to the cylinder head, an annealed copper gasket making the joint. Leakage past this gasket cannot be distinguished by sound from leakage past the admission valve, but the remedy is very simple.

Care should be taken that all valve rods are so adjusted that they do not prevent the valves from seating, as this trouble sometimes occurs when putting in new valves of perhaps slightly different lengths. A clearance between rod and valve of $\frac{1}{16}$ inch is advisable, except in the case of the needle valve, where the clearance is smaller.

The exhaust and admission valves sometimes stick, due to fouling of the stems. Ordinary machine oil works very well in preventing this on the admission valve. Nothing but kerosene, however, should be used on the exhaust valve stem, on account of the danger of carbonization.

Leakage past other gaskets, except the safety-valve gasket, or leakage past the joint of the cylinder head, can be both heard and seen, especially when the engine smokes. The remedy in the case of the gaskets is obvious.

The cylinder head makes a ground joint one-half inch wide around the cylinder. If this leaks, the best thing to do is to grind it in with flour of emery. We have tried copper gaskets and blow-hole cement, but neither gave satisfaction. The ground joint, with ordinary care, is absolutely tight. Sometimes the cylinder head leaks because it has not been bolted down tightly enough. The head of the 16 × 24 engine is held on by eight $2\frac{1}{4}$-inch nickel steel studs. We proceed as follows in tightening down the heads of our engines, which are of the above size: The nuts are first tightened down by hand with a 3-foot wrench. Next a 9-foot wrench is used, three men pulling on it with a long rope, going around the head once and giving about the same pull on every nut. Then the head is heated by admitting water and steam into the jacket until a temperature of about 140° F. is obtained. It is allowed to remain at this temperature for at least one hour. This is necessary to allow the studs to become thoroughly heated.

After the studs have become well heated the 9-foot wrench is used again with four or five men going around until everything is tight. Twice around is usually sufficient after heating the head.

Cracks sometimes occur in the cylinder head which cause leakage into the jacket water. If the jacket water discharges into a funnel beside the engine, as it should be arranged to do, this leakage can be detected by an irregular flow of the water and discharge of air-bubbles.

A badly cracked cylinder head is probably fit only for the scrap heap.

Leakage past the gasket of the safety-valve cage goes into the jacket water space, and can also be detected by an irregular discharge of the jacket water accompanied by bubbles of air.

A loss of compression will sometimes be caused by the clearance between piston and head increasing by wear from $\frac{3}{32}$ inch or $\frac{1}{8}$ inch, which is the proper clearance, to $\frac{1}{4}$ inch or more. The remedy is to lengthen the connecting rod by putting a shim $\frac{1}{8}$ inch thick or more between the connecting rod body and upper crank pin box.

We now come to the most serious leakage of all, which is the leakage past the piston. Aside from a cracked cylinder head, this leakage is the most serious because the hardest to remedy. It is caused usually by defective lubrication, clogging of the rings by carbon, broken or badly fitting rings, and rings that are worn out.

Defective lubrication is easily remedied by keeping the necessary quantity of oil in the crank case.

Clogging of the rings by carbon is often partly due to lack of lubrication, but is mainly caused by letting the engine smoke. The particles of carbon are caught in the piston ring grooves, and often rings become so firmly cemented in that they must be broken before they will come out. It is, of course, impossible to keep the engine from smoking once in a while from sudden and unexpected loads, but if the piston is kept well lubricated, these particles of carbon are not allowed to collect. Where the carbon has collected, if the carbonization is not in too advanced a stage a little kerosene poured on the piston and allowed to penetrate the grooves for the rings will aid greatly in freeing them. If, however, the carbonization has proceeded so far that this treatment, repeated several times, a day or two apart, has no apparent effect, the only resource is to remove the head and lift out the piston. Where a ring is taken out which has been cemented in, it is generally better to make a new one to replace it, as, even if it is possible to remove it unbroken, the chances are that it is so sprung out of shape as to no longer fit the cylinder. Frequently when rings are thought to be carbonized they are found to be broken. This may be caused by faulty material or construction. Sometimes rings are found to be very little worn, but they no longer retain their elasticity and have taken a permanent set. This is a sign of poor material. In choosing a material for repairs of almost any kind the best is always the cheapest, especially where the labor cost is the larger part of the expense. Cast-iron for

piston rings should be hard and close grained, and should have a high elastic limit. In making a set of piston rings it always pays to jig them. When a ring is jigged, it is first roughed out on the casting, allowing for finishing on the inside and outside. The ring is then cut off the casting, then cut and sprung together, and held there by pinning the ends, while a finishing cut is taken on the inside and outside. The result is that the ring when sprung to the size of the cylinder is truly circular. A ring that is turned to size on the piston casting and then cut and put on the piston will not fit the cylinder, no matter whether it is a straight or eccentric ring. Sometimes the cylinder is out of round, so a truly circular ring would not fit it. The ring should therefore always be fitted into the cylinder with red lead in the position in which it is to run, and then pinned on the piston in that position.

It will be noticed that most of the trouble from loss of compression is caused by needle valve leakage, and allowing the engine to smoke. There are two ways of detecting needle valve leakage: first, by a pound in the engine just before passing the top center, caused by the fuel leaking into the cylinder and igniting too soon; this is also an indication of a too early opening of the needle valve. Another way is by undue heating of the exhaust pipe and that part of the cylinder body surrounding the exhaust valve. These are usually indications of bad leakage, however, and to effectually forestall any tendency of the valve to leak it should be tested periodically by pumping oil up to the valve against the injection air pressure. By taking out the admission valve cage, the orifice of the needle valve is exposed and any leakage can be immediately detected. If it leaks, it should be ground in. In grinding in a valve a narrow seat is the tightest one. In the case of the needle valve which is $\frac{5}{8}$ inch in diameter, a bearing $\frac{1}{32}$ inch wide all around is the preferred one.

All fuel oil should be thoroughly screened through very fine wire gauze, since any impalpable, solid matter suspended in the oil will cause wear of the needle valve seat and consequent leakage.

Once every ten days is not too often to test the needle valve, and it should be made an opportunity for inspecting the engine generally. The exhaust and admission valves should be examined and reground if necessary. The crank case should be opened and the amount and condition of the oil noted. The level should be at about the center of the crank pin when on the bottom center, the oil consisting of a layer of about one-half inch thickness, the rest being water. Sometimes the oil is found in a thick, pasty condition and looks something like

raw liver. A couple of bars of yellow laundry soap thrown into the case will usually thin the oil up. This is sometimes caused by smoking of the engine.

All interior working parts should be inspected, and all bolts, nuts, and cotter pins tested, to make sure they are tight. The safety valve should also be examined to make sure it is free to move. The first heavy ignition in starting the engine, if the compression is good, should cause the safety valve to pop. If this does not happen, the valve should be examined at the next shut down, and if apparently all right, the pressure of the spring should be decreased.

Sometimes the engine shows a lack of full power and the exhaust is nevertheless clear. The trouble will then usually be found to be due to an insufficient supply of oil. This may be caused by the clogging of the supply pipe or leakage in the fuel pump. If there is no visible leak, *i. e.*, if the gaskets and plunger packing are tight, it is probably due to the suction valve becoming pitted. When such is the case, it should be ground in. Sometimes the seat of the suction valve is good, but owing to wear there is a little burr on the valve, which once in a while catches and prevents the valve from seating. Grinding will not remedy this, so it should be first faced off in a lathe. This should be done also when the valve is found scored. This can usually be detected when pumping up the first charge by hand for starting the engine. Sometimes the pump will take hold and sometimes it will not. When the injection air pressure is on the needle valve, a man should have to exert almost his full strength to pump up a charge of oil if the pump is in good condition.

Sometimes the double steel ball discharge check is affected. When this is the case, if a ball is found flatted it should be renewed.

In keying up the connecting rod of the engine great care should be taken to get both ends snug, yet with sufficient play to obviate heating. The reason the rod should be snug is that the clearance is only $\frac{1}{8}$ or $\frac{3}{32}$ inch between the piston and cylinder head, and while on the compression stroke the piston is jammed down and every bit of lost motion taken up, on the exhaust stroke this is not the case, and the piston is flung up with tremendous force—enough to lift the fly-wheel when the main bearings are slack.

A good way of telling whether the bearings are in free running condition is to let the engine roll over from the top center. If the bearings are free, the crank will pass the bottom center by about 45 degrees and then settle back to the bottom center. If they are too tight, the

engine will not pass the bottom center at all, or, if it does, will stick where it stops. This only applies to the single-cylinder engine, however.

We have had some trouble with the air compressors in the past. We would grind in the valves and find them a few days later caked with dirt and rust and the seats showing signs of corrosion. That trouble was entirely obviated by the use of one-quarter pint of soapy water in the low-pressure lubricator three times a day. Now we find the seats with a mirror-like polish and clean valves.

That may be accounted for in the following way: It is well known that iron does not oxidize rapidly except in the presence of carbon dioxide and moisture. The carbon dioxide in the compressed air, dissolved in the moisture condensed out of the compressed air in the inter-cooler, and thus formed weak carbonic acid, which in company with the oxygen of the air created excessive oxidation. The alkali in the soap was sufficient to neutralize this carbonic acid and consequently the oxidation did not occur.

After about nine months of continuous running the rings in the high-pressure cylinder are usually worn out and the piston $\frac{1}{32}$ inch loose in the cylinder. We then have the cylinder rebored, specifying a new steel piston, ground to fit cylinder, and a set of 8 cast-iron rings also to fit cylinder. We have put cylinders into commission repaired in this manner which for some time had no perceptible leak past the piston, although compressing up to from 750 to 1000 pounds per square inch.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, May 2, 1908.—The meeting was called to order by the President at 8.30 p. m. with 180 members and visitors in attendance. The minutes of the last meeting were approved as printed in the bulletin.

The President announced that the amendments to Article 1, Sections 3 and 5, of the By-laws were open for discussion, whereupon Mr. William Easby, Jr., Chairman Membership Committee, stated the reasons for proposing the amendments. On motion of Mr. L. F. Rondinella, seconded by Mr. W. P. Dallett, it was resolved that the amendments be amended to read as follows:

Article 1, Section 3: Change the final period to a semicolon, and add "but if he has not attained eligibility for Active Membership before reaching the age of twenty-seven years, he shall then be transferred to Associate Membership."

Article 1, Section 5: Add, "An associate member may be transferred to Active Membership by vote of the Board of Directors when the Membership Committee has certified that he has attained the necessary professional qualifications."

Upon motion of Mr. Hugo L. Hund, seconded by Mr. J. C. Trautwine, Jr., it was resolved that "The Engineers' Club of Philadelphia heartily indorses the objects of the Conference to be held at the White House, May 13th, 14th, and 15th, 1908, for the Conservation of the Natural Resources of the United States; and that it declares the necessity to be urgent for taking effective measures to check further waste, to encourage the judicious use of the natural resources of forests, minerals, and water-courses now remaining, and so far as is possible to restore these depleted resources, by Government and private efforts, to proper conditions."

Mr. S. M. Swaab, Active Member, presented a paper, "Construction Methods on Section Six, Market Street Subway." The paper was discussed by Messrs. J. C. Trautwine, Jr., Silas Comfort, and Charles M. Mills.

Business Meeting, May 16, 1908.—The meeting was called to order by the President at 8.30 p. m. with 158 members and visitors in attendance. The minutes of the meeting of May 2, 1908, were approved as printed in the bulletin.

The report of the Tellers on the election of new members was presented, and in accordance therewith Samuel Archibald Bullock, Clarence A. R. Euson, and J. Edward Whitfield were declared elected to Active Membership; Harry H. Appleton, Lesley Ashburner, and John Augustus Boers, to Junior Membership; and H. R. Goshorn to Associate Membership. The Tellers reported the result of the vote on the amendment to the By-laws as follows:

	For.	*Against.*	*Necessary for approval.*
Article 1, Section 3	91	5	64
Article 1, Section 5	87	9	64

The Secretary announced the death of William H. Robinson, Active Member, which occurred March 2, 1908.

Letters from the President of the United States, the Governor of Pennsylvania, Representatives R. O. Moon, Henry H. Bingham, and J. Hampton Moore, relative to the resolution of the Club on the Conservation of the Natural Resources of the United States, were read.

The matter of the increase in membership was brought up for discussion, and was discussed by Messrs. James Christie, W. P. Dallett, Henry Hess, H. H. Quimby, H. M. Chance, J. G. Brown, and the President. The following amendment to the By-laws was presented by Messrs. Henry Hess, Wm. S. Twining, and F. E. Dodge:

Article 1, (Add) Section 8. The total number of members of all grades, exclusive of Honorary Members, is limited to 750. The total number of Junior Members is limited to 10 per cent. of the authorized membership.

After some discussion it was decided to wait until fall to see whether it would be advisable to place a limit on the membership or not.

Mr. W. S. Reed, Visitor, presented a paper on "Sand—Its Use and Application in the Various Industries and Processes." The paper was discussed by P. A. Maignen. Mr. T. C. McBride's paper on "The Theory of Steam Condensers" was discussed by Messrs. H. M. Chance, J. C. Parker, D. W. Horn, and the President. Owing to the lateness of the hour, the President ordered that further discussion be held over until another meeting.

The thanks of the Club were extended to Mr. Reed for his paper.

Business Meeting, June 6, 1908.—The meeting was called to order by President Spangler at 8.15 P. M. with 140 members and visitors in attendance. The minutes of the meeting of May 16, 1908, were approved as printed in the bulletin.

The Secretary read a communication from Mr. Francis K. Worley relative to the formation of a company of engineers to be attached to the 3d Brigade of the National Guards of Pennsylvania. The Secretary also read a communication from Mr. Theo. Kolischer relative to transportation to the First International Congress of Refrigerating Industries, to be held in Paris, France, early in July, 1908.

The death of Carl Lieb, Active Member, which occurred May 17, 1908, was announced.

The report of the Tellers was read, and in accordance therewith, Henry DeHuff, Herbert Hollick, and Thomas Love Latta were declared elected to Active Membership; Walter Cornelius Aucott, Amos B. Engle, and Robert Frank Runge to Junior Membership; and James G. Biddle to Associate Membership.

In accordance with Article 5, Section 11, of the By-Laws, the following names were presented as nominations of the Board of Directors for membership in the Nominating Committee: Silas G. Comfort, E. M. Nichols, Edwin F. Smith, J. C. Parker, and Harrison W. Latta.

Dr. Henry Leffmann read a Memoir on the death of Mr. L. Y. Schermerhorn.

Mr. T. C. McBride, Active Member, presented some additional information on his paper, "Notes on the Theory of Steam Condensers," which was discussed by Messrs. L. H. Rittenhouse and E. M. Nichols.

Mr. H. S. Righter, Active Member, presented an illustrated paper, "A Short

Description of the Work of Elevating the Philadelphia, Baltimore & Washington R. R. Co.'s Tracks through the City of Wilmington, Del."

Mr. Myron H. Lewis, Visitor, presented an illustrated paper, "Waterproofing—An Engineering Problem." Owing to the lateness of the hour, it was decided to defer the discussion on these papers until a later meeting.

Special Business Meeting, July 31, 1908.—The meeting was called to order by Vice-President W. P. Dallett with 17 members in attendance. The minutes of the meeting of June 6, 1908, were approved as printed in the abstract.

The report of the Tellers was read, and in accordance therewith Thomas M. Eynon, Conrad Newton Lauer, John Meigs, Carl P. Nachod, Lee Raymond Stewart, and Ernest George Turner were declared elected to Active Membership; Henry Thomas McGaughan and Barclay White to Junior Membership; and William L. Geddes, Herbert Rice, and Homer Clyde Snook to Associate Membership.

The meeting adjourned at 4.15 p. m.

ABSTRACT OF MINUTES, BOARD OF DIRECTORS.

Special Meeting, May 6, 1908.—The meeting was called to order by President Spangler at 8.15 p. m. with Vice-Presidents Dallett, Devereux, and Easby; Directors Loomis, Perrot, Dodge, Clarke, Head, Quimby, Twining, Cochrane, and Develin, and the Secretary and Treasurer in attendance. Directors Christie and Ledoux reported inability to attend.

The President stated that the Board had been called together to consider financial matters with particular reference to the restaurant, and referred to the statement which he had sent to the members of the Board showing that we are running behind. On motion of Messrs. Dodge and Hess, it was resolved that the House Committee be instructed to receive estimates from caterers throughout the city, who would conduct the restaurant, taking over the Club equipment; also to ascertain what arrangements could be made toward having some one, not regularly engaged in the catering business, to cater for the Club exclusively.

A communication from the Trustees of the Bond Redemption Fund was read, desiring the Board of Directors to reconsider the rule requiring applications to be made for the redemption of bonds. This matter was left over for more careful and deliberate consideration.

The letter from Mr. James M. Dodge relative to the retirement of Club bonds by crediting them as initiation fees and dues was further considered, and upon motion of Mr. Hess, seconded by Mr. Easby, the following resolution, which had been prepared by Mr. Dallett, was passed and the Secretary instructed to communicate with Mr. Dodge.

Whereas: Certain holders of second mortgage bonds of The Engineers' Club of Philadelphia are desirous of having same cancelled, using the proceeds for the payment of initiation fees and dues of new members; therefore, be it

Resolved that holders of second mortgage bonds be permitted to surrender them for cancellation, receiving for same non-interest-bearing certificates in denominations of $25 each for the face value of the bond, and that such credit certificates shall be used for the payment of initiation fees and dues of active or associate members, under the following regulations:

1. Candidates for Active or Associate Membership, designated by holders of bond credit certificates, shall be subject to the provisions of the By-Laws governing membership and election of members.

2. The initiation fee of candidates so designated may be paid by surrender of bond credit certificate, said certificate to be returned should the candidate fail to be elected.

3. The dues of a newly elected member or associate, so designated, must be paid for not more than two half years after election by surrender of bond credit certificates.

Adjourned.

Regular Meeting, May 16, 1908.—The meeting was called to order by President Spangler at 4.30 p. m. with Vice-President Dallett and Directors Loomis, Dodge, Clarke, Head, Quimby, Twining, Christie, and Develin, and the Secretary and Treasurer in attendance. The minutes of the regular meeting of April 18, 1908, and the special meeting of May 16, 1908, were read and approved.

The death of William H. Robinson, Active Member, which occurred March 2, 1908, was announced.

The resignations of Wm. S. B. McCaleb, Augustus A. Miller, and E. P. Coles were read, and the Secretary was ordered to communicate with them, with a view of having them retain their membership.

The House Committee reported, giving a statement of the house and restaurant costs, which was referred to the Finance Committee.

Upon motion the President and Treasurer were authorized to execute a new contract with the Bell Telephone Co. for the house telephone.

On motion, the House Committee was authorized to retain, at $50 per year, the Electrical Inspection and Audit Company as auditors in connection with electric lighting.

The Finance Committee was authorized to arrange for a uniform classification of Club accounts.

The Publication and Library Committees were ordered to investigate the matter of cost, etc., of the Club publications, and the exchange list of this Club with other publications.

Upon motion it was decided to retain George Shellem as night watchman at $50 per month, but no meals are to be included as part of his compensation.

The President ordered that the next meeting of the Club should be a business meeting, at which time the Board of Directors will, in accordance with the By-Laws, submit to the Club its nominations for membership in the nominating committee.

Adjourned.

Special Meeting, June 6, 1908.—The meeting was called to order by President Spangler at 3.30 p. m. with Vice-Presidents Dallett, Devereux, and Easby, Directors Ledoux, Dodge, Clarke, Quimby, and Twining, and the Secretary in attendance.

The death of Carl Lieb, which occurred May 17, 1908, was announced.

The resignation of T. Carpenter Smith was read and accepted as of December 31, 1907.

A communication from Dr. Henry Leffmann, Chairman of the Board of Trustees of the Bond Redemption Fund, asking authority to secure a safe deposit box for the use of the Trustees at the price of not over $3.00 per year, also asking authority to proceed with the purchase of Club bonds from the funds which the Trustees now have on hand, was read.

Upon motion, the following names were submitted to the Club as the Board of Directors' choice for the Nominating Committee for the coming year: Silas G. Comfort, E. M. Nichols, Edwin F. Smith, J. C. Parker, and Harrison W. Latta.

The Treasurer submitted his monthly report as follows:

Balance April 30, 1908, Club Account		$2515.43
May Receipts		1440.93
		$3956.36
May Disbursements		2099.54
Balance Club Account		$1856.82
Distribution:		
In Girard Trust Co	$15.83	
In Colonial Trust Co	1330.73	
In Colonial Trust Co. Savings acct	100.60	
In West End Trust Co. Savings acct	109.66	
Petty cash	300.00	
		$1856.82

Upon motion, the Treasurer was requested to submit to the Board, in his monthly report, a trial balance of the Club's books.

Upon motion, the Secretary was instructed to send out a membership blank with the next notice.

The Finance Committee reported progress.

The House Committee made a routine report.

The Library Committee requested that the House Committee be authorized to fit up shelves in the library at a cost not to exceed $50. Upon motion this authority was granted.

Adjourned.

Regular Meeting, June 24, 1908.—The meeting was called to order by the President at 4.30 p. m. with Vice-Presidents Dallett, Easby, and Devereux, and Directors Dodge, Clarke, Head, Cochrane, and Develin, and the Secretary and Treasurer in attendance.

The resignations of Wm. Williamson and M. Ward Easby were read, and the President was asked to communicate with Mr. Williamson with a view of having him retain his membership, and the Secretary was instructed to communicate with Mr. Easby for the same purpose. The resignation of Wm. B. McCaleb, Active Member, was accepted as of June 30, 1908.

The death of Geo. F. Payne, Active Member, which occurred on June 7, 1908, wsa announced.

A letter from Mr. James M. Dodge was read, stating that it was not agreeable to the Link Belt Company to retire the Club bonds in their possession, by letting

same apply on initiation fee and dues of members by the method proposed by the Board under date of May 6, 1908. Upon motion this letter was referred to the Finance and Membership Committees for report to the Board.

Mr. Macbeth, of the Electrical Audit Company, was introduced and discussed the matter of electric lighting of the Club-house, and finally recommended that the Club sign a $600 minimum yearly contract. Upon motion the President and Treasurer were authorized to enter into such a contract with the Philadelphia Electric Company.

Upon motion, the House Committee was authorized to secure a license for the coming year for the sale of liquors in the Club-house.

On motion, the dues of members elected at the business meeting of the Club on June 6, 1908, were remitted for the first half of the year.

The meeting adjourned at 5.45 P. M.

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1908

President

H. W. SPANGLER

Vice-Presidents

Term Expires 1909
W. P. DALLETT

Term Expires 1910
WASHINGTON DEVEREUX

Term Expires 1911
WM. EASBY, JR.

Secretary
H. G. PERRING

Treasurer
GEORGE T. GWILLIAM

Directors

Term Expires 1909	*Term Expires 1910*	
J. W. LEDOUX	J. O. CLARKE	JAMES CHRISTIE
JOHN T. LOOMIS	W. S. TWINING	HENRY HESS
EMILE G. PERROT	FRANCIS HEAD	H. P. COCHRANE
F. E. DODGE	HENRY H. QUIMBY	RICHARD G. DEVELIN

STANDING COMMITTEES OF BOARD OF DIRECTORS

House—W. P. DALLETT, JAMES CHRISTIE, W. S. TWINING, J. T. LOOMIS, HENRY HESS.

Finance—JAMES CHRISTIE, F. E. DODGE, J. W. LEDOUX.

Membership—WM. EASBY, JR., J. O. CLARKE, H. P. COCHRANE.

Publication—HENRY H. QUIMBY, RICHARD G. DEVELIN, FRANCIS HEAD.

Meetings—W. S. TWINING, J. O. CLARKE, H. P. COCHRANE.

Library—WASHINGTON DEVEREUX, F. E. DODGE, H. P. COCHRANE.

MEETINGS

Annual Meeting—3d Saturday of January, at 8.15 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8.15 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

Vol. XXIV. OCTOBER, 1908. No. 4

PAPER NO. 1059.

THE THEORY OF STEAM CONDENSERS.

THOS. C. McBRIDE.

(Active Member.)

Read May 16, 1908.

IT often happens that engineers trained in other branches of the profession are called upon to consider or operate steam condensers. It has been thought that a statement of the fundamental laws governing the operation of condensers would be interesting and useful, particularly since the steam turbine has made the condenser a much larger factor in the power plant. In the days of the steam-engine power plant condensers were small, and an inch of vacuum one way or the other meant little or no difference in fuel consumption. Nowadays the condensing machinery requires more room and more attention than the turbine it serves, every small fraction of an inch of vacuum that can be gained means a large saving of fuel, and if the engineer is to properly attend to the efficiency of his condensers, he should know their theory.

Before entering into any discussion of this subject it is worth while considering the measurements to be taken and the instruments employed.

The pressure in the condenser that is to be measured is expressed by two different methods. One method states this pressure as so many inches head of mercury below the atmospheric pressure, and is commonly stated as "vacuum." The other method is the stating

of this pressure as being so much above zero pressure, and is commonly stated as "absolute pressure," and expressed in inches head of mercury or pounds per square inch.

The former method involves an understanding as to the atmospheric pressure on which it is based, generally presumed as 30″ barometer. Thus a vacuum of 26″ based on 30″ barometer means an absolute pressure of 4″ of mercury. Statement of the condenser pressure as a "vacuum" is the older method, and is almost universally used colloquially; but statement as absolute pressure is much more convenient, as it does not require any accompanying explanation as to what it is based upon.

Measurement of "vacuum" by the ordinary dial (Bourdon tube) gauges is by far the most common method, but is not only inconvenient because a simultaneous reading of the barometer is required, but is also unreliable because these gages are rarely found in adjustment or to remain adjusted. For pressures less than 4″ the writer has found that estimating the temperature by the hand, and from that the vacuum, is much more reliable than reading the gages usually found in power plants. Measurement of "vacuum" by the full-length mercury column, where both it and the barometer are carefully read and precautions are taken to have pure clean mercury, can be made with scientific accuracy, but the necessary readings are such that power plant operatives must be specially trained if their readings are to be depended upon. By far the best method of measuring the pressure in condensers is by the absolute mercury gages composed essentially of a U tube, closed at one end and the other end connected to the condenser. The closed end of the tube is first filled with mercury and heated in a flame; the U is then turned upright and the open end connected to the condenser. Since there is then an absolute vacuum in the closed end of the U, the difference in level of mercury in the two legs of the U is the absolute pressure.

Care must be taken in connecting vacuum gages of any kind that the readings may not be affected by columns of water lying in the connecting pipes. The best location for gages is right on the condenser or piping. Gages may be depended on when located above the point where their connecting piping enters the condenser and connected with a pipe large and straight enough to drain the water of condensation back to the condenser, but gages located below the point of connection to the condenser are always to be questioned, even if the piping has been blown out.

Few thermometers, particularly those with metal scales, are to be depended upon for more than ordinary accuracy, and for scientific work not only the best standardized thermometers are necessary, but also great precaution in their use.

It must not be thought that these are trivial matters. Neglect of even ordinary precautions in temperature and vacuum readings is without doubt the cause of many of the impossible statements we hear. People do not seem to realize that they might as well be without a feed-water heater in a turbine plant as to be deprived of say 1½″ vacuum; yet readings that will not check up within this amount are unfortunately frequent.

The first essential to a knowledge of the theory of steam condensers is a thorough understanding of the laws governing the physical condition of the steam, air, and water handled in the condenser.

The physical condition of low pressure steam is given in the steam tables of the hand-books with which all engineers are familiar. Particularly for the higher vacuums carried in steam turbine condensers care must be used in reading these tables because of the different assumptions as to the absolute pressure which represents zero "vacuum," that is, the pressure of the atmosphere. Most hand-book tables for convenience assume the atmospheric pressure at 14.7 pounds. In these tables the column indicating "vacuum in inches of mercury" has its zero opposite 14.7 in the column headed "absolute pressure in pounds per square inch." As 14.7 pounds pressure per square inch is equal to 29.92″ head of mercury, it is evident that the figures in the "vacuum in inches of mercury" column indicate vacuum based on 29.92″ barometer. Most condenser contracts have their vacuum guarantees stated either as based on 30″ barometer or else in pounds absolute pressure. It it often presumed that one pound absolute pressure is the same as two inches of mercury. The following table will serve to point out the great difference, the first column being taken from a table where zero "vacuum" equals 14.7 pounds per square inch absolute pressure:

	28″ Based on 29.92 Barometer.	2″ Absolute (28″ Based on 30″ Barometer).	One Pound Absolute.
Temperature	100°	101.4°	102°
Relative volume of steam and water	22,098	21,250	20,881

Thus it is seen that these apparently negligible differences in phraseology may mean a difference of 5 per cent. in volume, and in the smaller ranges of temperature a still greater difference.

Exhaust steam as it exists in practice in condensers and their piping does not conform to the steam tables because of the admixture of certain amounts of air with it. The temperatures and pressures of this mixture of air and steam follow Dalton's law. Under this law the total pressure at any point is the sum of the individual pressures of the air and of the steam in the mixture at that point, whereas the temperature is that due to the steam at its individual pressure as if alone. In most condenser problems making use of this law the temperature and the sum of the individual pressures are given, the latter being the absolute pressure in the condenser. The individual pressure of the steam will be that due to the temperature and can be taken from the steam tables. The individual pressure of the air must then be the difference between this individual steam pressure and the total pressure. Having obtained these individual pressures, and knowing therefore that the relative volumes of the air and steam if separated must remain in the same proportion as their individual pressures, it is possible to calculate the exact amount of air present and to trace this amount through the condensing process.

It is evident from the above that there must be a gradual reduction of the temperature of the mixture of steam and air as it passes through the condenser, accompanied by a corresponding gradual increase in the proportion of air to the steam. The fact that the temperature of the steam in a condenser is not the same at all points in the condenser does not seem to be fully appreciated by engineers generally, even though recognition of this fact is of the greatest importance in controlling the proper design of condensers and in securing the best results in their operation. This lack of general familiarity with the actual conditions may be due to the methods of consideration of the subject usual in most publications in English, which generally presume the steam as steam alone in their calculations, leaving for a small paragraph a statement that the vacuum will not be as high as might be expected from the temperature due to the presence of air.

It is interesting to compare the volumes before and after condensation of the steam and air mixtures in the proportions generally found in actual practice. The simplest example can be taken from the case of an air-pump and surface condenser, say presuming 70° injection and 26″ vacuum, and an air leakage a little large, and taking four separate

instances, one with a condenser cooling the mixture of air, steam, and water going to the air-pump down to 110° and the others to 90°, 70°, and 50° respectively. These volumes are shown in Table I.

TABLE I.

	Absolute Individual Pressures in Inches of Mercury.			Volumes when Separated Based on Equivalent Volume of Water being Unity.			
	Steam.	Air.	Total.	Steam.	Air.	Water.	Total.
In exhaust pipe	3.9984″	.0016″	4″	11000	4.37	0	11004.37
In air-pump suction at 110°	2.58″	1.42″	4″	7.74	4.26	$\frac{16687}{16699}$	13
In air-pump suction at 90°	1.41″	2.59″	4″	2.21	4.11	$\frac{29620.7}{29627}$	7.3
In air-pump suction at 70°	.73″	3.27″	4″	.88	3.95	$\frac{53368.2}{53373}$	5.8
In air-pump suction at 50°	.36″	3.64″	4″	.37	3.82	$\frac{108927.8}{108932}$	5.2

Having established the principle that the practical condensation of steam is a gradual reduction of its volume and temperature, it is evident that the counter-current principle should be applied whenever possible. The circulating water will be used to its fullest extent to carry off heat when it is heated all the way up to the temperature of the exhaust steam. The mixture of air and steam leaving the condenser can be handled to the best advantage by the air-pump when it is cooled all the way down to the temperature of the circulating water-supply. Counter-current arrangement is therefore essential to the best circulating water and vacuum pump efficiency and should be used where other more desirable features are not sacrificed by it.

Passing on to the consideration of various types of condensers, surface condensers will first be considered, then the various types of jet condensers.

Surface condensers and wet air-pumps for steam-engines are generally in this latitude designed for 70° F. condensing water-supply temperature; 110° F. condensing water discharge temperature; 110° F. air-pump suction temperature; 10 pounds of steam condensed per

hour per square foot of condensing surface; air-pump displacement thirteen times the volume of the condensed water.

These presumptions are not the results of engineering calculations, but are based on results of practice in large numbers of plants, and therefore represent usual conditions of air leakage, condition of tubes as to dirt, etc. They imply, further:

(*a*) *A ratio of 26 pounds of condensing water to one pound of steam condensed.*

The condensing water is heated from 70° to 110°, therefore carrying off with it 40 B. T. U. per pound. The "latent" heat of the steam condensed is 1026 B. T. U. per pound, and each pound, after condensation at the vacuum temperature of 125°, must be cooled further down to 110°. The total heat to be removed is therefore 1041 B. T. U. per pound of steam condensed, requiring $\frac{1041}{40} = 26$ pounds of circulating water.

It is usual in discussing this feature of condensers to state that practice has shown that it is possible to heat the circulating water to within 15° of the temperature of the steam coming to the condenser, and reference is rarely made to the fact that this presumption contemplates making use of but $\frac{40}{55}$ of the capacity of the circulating water to carry off heat. Good engineering dictates that as much attention be given to the 15 heat units carrying capacity of the circulating water that are wasted as to the 40 that are used, to the end that as much as possible of the 15 wasted units may be saved. It must be remembered that there are many plants doing much better than this, but the fact that the presumptions stated are the results of years of experience and almost universally used in designing condensers indicates that there must be some feature or features, in either the design or operation of condensers, rendering necessary or advisable the provision of this seemingly excessive amount of cooling water. It is evident that anything tending to increase the final temperature of the cooling water will permit of a reduction in its quantity with a consequent saving in expense of pumpage and first cost and size of circulating water-pumps.

It is not generally known that it is possible in an appropriately designed surface condenser under certain conditions to heat the condensing water up to a temperature one or two degrees above the temperature due to the vacuum. Just why the water should become hotter than the steam heating it is hard to explain, unless it be that the energy of velocity of the steam and entrained water is sufficient to cause the extra heating.

Looking about for means of effecting economy in condensing water, it is evident that counter-current design is essential, particularly in condensers having high air leakage to contend with, and therefore likely the greatest differences in temperature of the steam in their different parts. Low air leakage, by raising the average temperature as well as affecting favorably other features of the condenser, to be discussed later, will favor the high heating of the circulating water. It is no unusual thing to find condensers supplied with two or three times the circulating water they are actually using in a misdirected endeavor to improve vacuum which is being limited by other features of the condenser. In selecting sizes of circulating pumps proper regard should be given to summer and winter temperatures, and whether maximum loads are summer or winter loads. Thus winter lighting peaks for the same condenser and air-pump require less water than summer trolley peaks.

(*b*) *A heat-transferring capacity of the surface of* 300 *B. T. U. per hour per square foot per degree difference of vacuum and average water temperatures.* This has usually been calculated on the basis of $\frac{70 + 110}{2} = 90°$ average temperature of the circulating water on one side of the surface; 125° temperature of the vacuum on the other side of the surface—a difference of 35°. Ten pounds of steam per square foot, and each pound calling for the removal of 1041 B. T. U., requires each square foot to transmit 10,410 B. T. U. total, or, say, 300 B. T. U. per square foot per degree difference per hour.

In the face of record transfers, calculated on this basis, of nearly twice this amount in practice and three times and over this amount in experimental work, it is evident there must be some potent reasons compelling the practice of designers to recommend and furnish the amount of surface customary. Doubtless the most important consideration that has brought about this custom is the tendency of condenser tubes to become coated with slime on the inside and oil on the outside, in some localities quite rapidly, so that the selection of the amount of surface becomes more or less a question of the frequency of cleaning permissible. Another reason is that under our present system of neglecting entirely the exact consideration of the amount of air passing through condensers, designers probably unconsciously have formed the habit of designing condensers for large amounts of leakage, these condensers requiring an otherwise unnecessary amount of surface both because the excessive air has lowered the temperature in the condenser, and therefore decreased the differ-

ence of temperature inside and outside the surface, and also because air has a tendency to seriously decrease the amount of heat the surface can transmit.* If the designer is assured in advance that a certain definite low amount of air will not be exceeded, he should be able to so plan his counter-current arrangement and velocities that the heat transfer will be high; but if he must provide large areas for a dreaded unknown large amount of air, even the absence of this air will not result in high heat transfers because the velocities will then be low and some of the surface will likely be idle.

All of the features which increase total heat transfer tend also to increase final circulating water temperature. It is evident, therefore, that surface condensers should be designed with counter-current effect up to the point where the length of the opposite paths of the steam and water begin to tell in friction loss; and equally evident that while the designer plans his steam path for the greatest amount of air he is likely to encounter, he cannot provide for or obtain a highly efficient condenser, and must therefore furnish a larger amount of surface and provide for more water than is otherwise necessary.

(*c*) *The provision of an air-pump capacity thirteen times the volume of the condensed water* implies that there is expected a certain definite and calculable amount of air mixed with the exhaust steam. More air than this amount would result in the failure of the apparatus to maintain the presumed vacuum with the presumed conditions, and necessitate higher speed or a larger air-pump. Less air would result in a higher vacuum than presumed or permit of proportionately less displacement than 13 to 1.

The question of air in condensers is of very great importance, but its study from a quantitative standpoint seems to have been entirely neglected. The writer has presented a paper to the American Society of Mechanical Engineers, "A Plea for the Scientific Consideration of Air Leakage in Condensers," which has been accepted for the June meeting in Detroit, and which treats of this feature of condensers. This paper advocates the measurement of air leakage by air-pump displacement and temperature, and the limitation of its amount in condenser contracts and their guarantees, and it is hoped will result in a better general understanding of this feature of condensers.

Particular attention is called to that feature of table I, on page 321,

* See "Air in Relation to the Surface Condensation of Low Pressure Steam, an Experimental Study of Condenser Problems," James Alex. Smith, Victorian Institute of Electrical Engineers, Dec. 6, 1905.

which shows that 11,000 volumes of steam and 4.37 volumes of air mixed with it, if cooled to

110°	will be reduced to	13 volumes
90°	" " " "	7.3 "
70°	" " " "	5.8 "
50°	" " " "	5.2 "

The capacity of an air-pump to handle a certain amount of air is therefore largely influenced by the power of its condenser to reduce the temperature. Thus with 26 vacuum a condenser that will cool to 90° will require an air-pump but 55 per cent. as large as a condenser that cools only to 110° to remove the same amount of air.

Surface condensers for 28″ vacuum are usually designed on presumptions differing only from those for 26″ in the temperature range. As this range is much smaller, greater care is required to obtain high efficiency, and the suggestions offered for 26″ all apply in a greater degree. The air-pump used for 28″ vacuum is usually a "rotative dry vacuum pump," taking the air from a cooler or a cold part of the condenser, the condensed water being removed by a hot well-pump. This so-called "dry" air-pump system not only permits of the air being taken off cooled to the least possible volume, but also that the condensed water be taken from the hottest part of the condenser, and therefore where used for boiler feed saving some of the heat of the condensed steam. This paper will not permit of dealing with this condenser at the same length as the discussion of the air-pump and surface condenser, but it is evident that an almost exactly identical discussion will apply, requiring only that the figures be changed to suit the 28″ temperatures and pressures.

Jet condensers with wet air-pumps are usually designed for 26″ vacuum with 70° F. condensing water-supply temperature and 110° F. condensing water-discharge temperature, this temperature also necessarily being the air-pump temperature; and an air-pump displacement fifty-two times the volume of the condensed steam.

These presumptions, like those for the surface condenser, are the results of practice, and have no theoretical basis. They imply further:

(*a*) *A ratio of* 26 *pounds of condensing water per pound of steam condensed,* just as in the surface condenser. Here too but $\frac{40}{55}$ of the heat-removing capacity of the condensing water is presumed to be used. The same high economy of condensing water which might be possible in a surface condenser would not be possible in a jet condenser with wet air-pump, because counter-current effect is not possible in

this type condenser. It is evident, however, that economy of condensing water is especially desirable in a jet condenser because the circulating water carries air into it, not only lowering the vacuum, but also requiring more work of the air-pump for air removal. It has been shown that increasing the amount of injection water may improve the vacuum up to a certain point, beyond which more water will not further improve, and may decrease the vacuum because of the additional amount of air this water will carry into the condenser (see Hausbrand's "Evaporating and Condensing Machinery").

(*b*) *The provision of an air-pump capacity of fifty-two times the volume of the condensed water* indicates an assumption of air leakage somewhat higher than presumed by surface condenser ratings (see writer's A. S. M. E. paper mentioned above).

The jet condenser with dry air-pump is usually rated on presumptions derived from presumptions of other types, such as have been mentioned. This condenser may be of either the "barometric" or "centrifugal jet" type, and has of late years been used quite extensively for 28″ vacuum on steam turbines. Since the air and the water are removed separately, it is advisable theoretically to cool the air to the temperature of the injection and to heat the water to the temperature of the exhaust steam, this condition representing the least power requirement for removing the air and the greatest economy of condensing water. It is evident that this condition will obtain if the condenser is made counter-current.

Weiss has made a very thorough and creditable study of counter-current jet condensers, and the conclusions derived from this study are probably most conveniently accessible in brief form in his American patent specifications, No. 496761, dated May 2, 1893. Speaking of the "ideal point" as that of heating of the condensing water to the temperature of the vacuum and cooling of the air to the temperature of the injection, he explains the phenomena of the change from "counter-current" to "parallel current" "as soon as the ideal point is reached," and the impossibility of operating a counter-current jet condenser continuously at the "ideal point." The method by which his separator with its attached vacuum-breaking air inlet valve temporarily reduces the vacuum as soon as the attainment of the "ideal point" has caused the change from this condition to the less efficient condition of "parallel current" is fully explained. The first claim reads:

"A method of condensing steam and other vapors by counter-

currents, alternating with parallel currents, in which the condensation effected at intervals by the parallel currents is brought back to condensation by counter-currents by temporarily admitting air into the space of the condenser in which the air has been rarefied substantially as specified."

American designers of jet condensers with dry air-pumps have generally used a "cooler," through which the air from the condenser passes on its way to the vacuum pump. All or some of the incoming injection water is passed through the cooler, so that the air leaves the condenser reduced practically to the injection temperature. It is evident that with this system the first part of the condensation is "parallel-current," while the latter is "counter-current," and that for a definite proportion of air in the condenser, the tail pipe temperature, and consequently the efficiency of the injection water, will depend on the relative cooling effect of the condenser and the cooler. It is therefore advisable to make the cooler as large as possible and of the counter-current type, taking care that it be not so large as to cause the operating troubles of the counter-current condenser described by Weiss. Barring the possibility of a greatly excessive amount of air, there is no reason why the air removal efficiency of the cooler type of jet condenser should not be perfect and the condensing water efficiency well within the limits of practical requirements.

Although time will not permit a detailed consideration, it is evident that there are possibilities of improving the efficiencies of condensers as ordinarily found in operation, from the standpoint of both the designer and the operator. The operator should understand that the cooling effect as determined by the amount of circulating water supplied, the heat-transferring effect, or the ratio of air-pump capacity to air leakage may, any one of them, limit the vacuum obtained, and that under these conditions any increase in the others will be energy wasted in the wrong direction. The operator must also understand that air in condensers is directly opposed to efficiency, not only as to vacuum, but also in the condensing water and the heat transfer, and therefore give every attention to the reduction of air leakage.

From the standpoint of the designer, while he follows precedents the results of anticipation of the worst conditions likely to be encountered, condensers cannot be rationally designed for the work they will actually have to do, and cannot therefore have the highest efficiency.

The suggestions of this paper should lead to a realization of the

possibilities and necessity of scientific treatment of steam condensers, as this must eventually result in an increase in vacuum and reduction of cost of vacuum.

DISCUSSION.

Mr. McBride.—I doubt whether there is any feature of power generation which has received so little scientific attention as the condenser. Condenser design is necessarily almost entirely empirical, chiefly because the conditions that are to be met as to air-leakage must be guessed at in advance. The great amount of air present in condensers is not generally realized. It is not unusual to find one-half or two-thirds of a condenser having more air than steam in the mixture of air and steam in these parts. The major part of the steam may be condensed in the first half or first third of the condenser, leaving a mixture of air and steam, with air in the majority in the balance of the condenser.

I tried to enlarge in the paper on the question of the quantities to be measured. The old-style method of measuring and thinking of a vacuum considers the pressure in the condenser as being so much below that of the atmosphere, and is not a good method. We desire in practically all of our calculations to know the absolute pressure in the condenser. To obtain this by reading a mercurial column and a barometer we measure two large quantities and take the difference, which means a large probable error, because this difference is generally small. It is because of this large probable error that an absolute gage like that shown here a few weeks ago is much more reliable than a measurement of the vacuum by gage or mercury column and a barometer. An error of 1 inch either way in a gage reading 28″ vacuum is not an error of 1 part in 28 in the absolute pressure which it is desired to measure. This error would indicate either 1″ or 3″ absolute, and the reading might therefore be anything from 50 per cent. to 150 per cent. of the actual amount. As but few gages are correct to within 1″ in the neighborhood of 28″ vacuum, and as the temperatures corresponding to 1″, 2″, and 3″ absolute pressure are approximately 75 degrees, 100 degrees, and 115 degrees respectively, the correctness of the statement in the paper that these vacuums could be more closely estimated by the hand than by most gages will be appreciated.

Mr. Rittenhouse.—I have enjoyed this interesting discussion, and also the original paper, and have found many technical points explained that we have not been able to find discussed anywhere else. I notice Mr. McBride has laid particular stress upon counter-current arrangements. Is that principle as applied to condensers new, or comparatively new? Also, do not the majority of surface condensers employ it, and is there any increase in cost in that construction over other constructions?

Mr. McBride.—All surface condensers should be counter-current; some types of jet condensers are partially or fully counter-current. Counter-current effect in condensers is not new; indeed, it is very old, but the scientific study of the efficiency of condensers is comparatively new, having become necessary since the advent of steam turbines with their requirements of much higher vacuums.

H. M. Chance.—I note a statement in regard to the possibility of heating the water to a greater temperature than the assumed temperature of the exhaust steam. The statement I refer to this: "It is not generally known that it is

possible in an appropriately designed surface condenser under certain conditions to heat the condensing water up to a temperature one or two degrees above the temperature due to the vacuum." I would like to ask whether by that we are to understand that under certain conditions it is possible to heat the water higher than the observed temperature of the steam, or the assumed temperature of the steam. It seems to me this is a distinction that is rather important. It is assumed that steam under a certain pressure has a certain temperature. It seems to be thought that there may be a little superheating, *i. e.*, heating to a temperature above the assumed temperature due to the vacuum. The paper indicates that the possible source of that heat is due to the heat of the entrained water, but it is possible that the transformation of kinetic energy may explain the rise in temperature. I had an experience myself that may be of some interest to the Club. I built a home-made heater to work on the exhaust from a direct-connected steam pump. After the heater was in operation I found it was heating the water to a greater temperature than 212°. In other words, it was producing steam. The exhaust was open to the atmosphere, and I had always been taught that when steam expanded to atmospheric pressure, its temperature was 212° or lower; but for years we heated that water to a greater temperature than 212°. We had a tap used for washing purposes, and whenever that tap was opened, steam would blow out with the water. I would like to ask whether, in cases of the kind mentioned by the author, the actual temperature of the steam has been taken and compared with the temperature of the water in the condenser.

Mr. McBride.—The water is heated above the actual temperature of the water in the condenser. I do not know how to explain it, but accurate tests have been made, and Prof. Weightman, who read a paper before the Naval Architects of England, in testing some experimental condensers, found 2 or 3 degrees higher temperature at the discharge at certain capacities of the condenser; that is, you had to have the condenser working about as hard as it could work in order to get the effect. The same results were found in tests of 3000 K. W. engine-driven sets of the No. 1 water type. The condenser discharge at about nominal load was at a higher temperature than the vacuum temperature shown by thermometers in the discharge pipe. However, you have not only to know the thermometer, but you have also to know the man who uses it, when you speak of temperatures, and that is one of the difficult features of trying to interpret any experiments that may have been made. Some thermometers will run off perhaps one or two degrees, and it may be stuck in all the way to 211, so that you can just see 212. It is almost impossible, from the way tests have been published, to know whether the man who used the thermometer has used it right. How is it so many people say we can have entrained water in superheated steam?

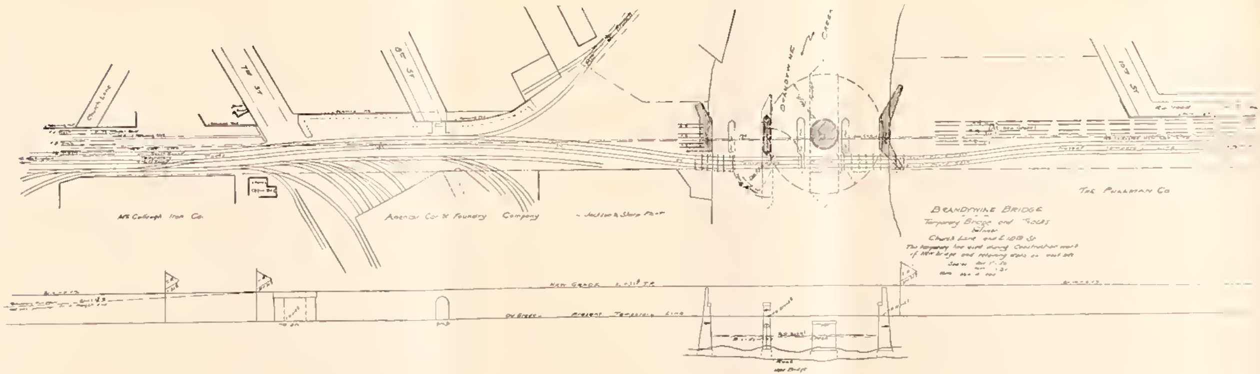
Dr. Chance.—I would like to ask whether any member of the Club has ever had an experience similar to that which I have mentioned, namely, a feed-water heater that would actually produce steam when working with steam from the exhaust into the atmosphere?

Mr. Horn.—We would have to lay aside the first law of thermo-dynamics, that heat does not rise above itself from a point of lower temperature to a point of higher temperature.

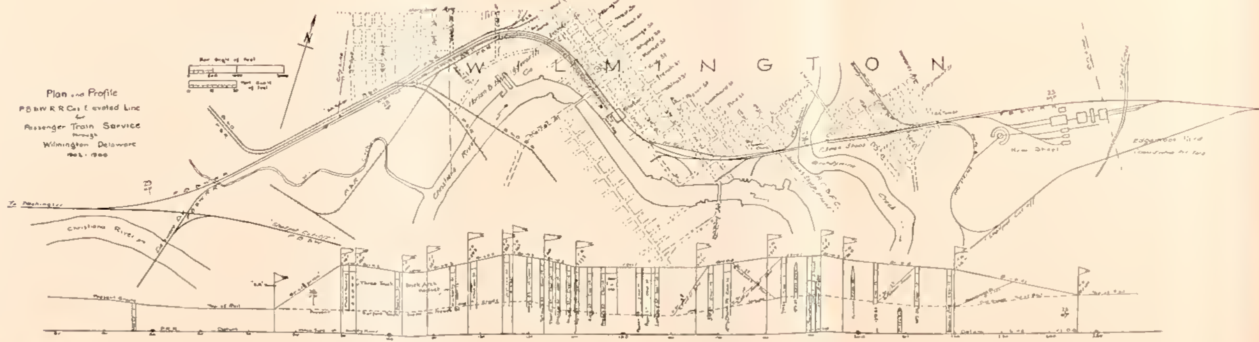
Dr. Chance.—Not necessarily: we merely have to assume that the escaping steam must be of a higher temperature than 212°.

President Spangler.—It carries more energy than ordinary steam. I can perhaps give you a collateral instance of that sort. Some years ago a patent was taken out by Prof. Rowland, of Johns Hopkins University, for a new scheme for superheating steam, and the scheme was to use the steam in motion to superheat the rest of the stuff. The energy came all right from the boiler back of it. It has been proved long since by actual experience, and when you open the ordinary valve in the steam-engine, if you measure the temperature back of the piston, it will be higher than the temperature in the boiler. You will carry away more heat than heat as steam, and you can use that heat to do what you please with. The experiment has been made over and over again by measuring the heat in the steam back of the piston. You are bringing in additional energy from the steam in the boiler. As far as the boiler is concerned, when you open the valve over a boiler and discharge the steam out of it, you are discharging the steam at a higher pressure. It drops down to a lower pressure, but you do not wipe out the additional energy that is there. The steam is still there and available to do something with. Prof. Rowland took the steam out of a boiler and simply let it run into space where it was superheating itself.

Dr. Chance.—In the case in point, we were running a pump at about 60 pounds pressure; it was a Worthington type of pump; cylinders 8″ by 12″; the heater was probably 20 feet distant from the pump and the exhaust was a 3-inch pipe. The heater was simply a 6-inch cast-iron pipe containing six or eight $\frac{3}{4}$-inch pipes, through which the feed water was passed; and when we attempted to take water out of that, steam would blow out through the tap. The superheating of the steam was doubtless due to the velocity of its discharge through the heater.



Brandywine Bridge
Temporary Bridge and Tracks
between
Church Lane and E 10th St
The Pullman Co
American Car & Foundry Company
New Grade
Present Temporary Line



Plan and Profile
P B & W R R Co's Elevated Line
for
Passenger Train Service
through
Wilmington Delaware
W I L M I N G T O N
Christiana River
Brandywine
Present Grade
Top of Rail

Paper No. 1060.

ELEVATING TRACKS OF THE PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD THROUGH WILMINGTON, DEL.

H. S. RIGHTER.
(Active Member.)

Read June 6, 1908.

The P. B. & W. R. R. Co. has about completed the work connected with elevating its tracks for a distance of about three miles, through the city of Wilmington, Del., the new grade being from 15 to 20 ft. above the old grade. The new center line practically coincides with the old for about two-thirds of the distance, except for about an equal distance each side of the station, where at the north end the line has been changed to better the alinement, and south of the station it has been moved off of Water Street to the new right of way. The ordinance giving the authority to elevate required the work to be started before February 1, 1902. Work was started January 29, 1902, in the square between Market and King Streets and along Water Street.

On the completion of the retaining wall along Water Street and the abutments for two tracks at King and Market Streets, work was started on the adjoining squares going north to French Street and south to Orange Street. On account of delay in purchasing all the property required in these blocks, work was prosecuted very slowly.

After completing this part of the work for two tracks, work was started on the north end of the line, between Brandywine Bridge and Todds Cut. Owing to the conditions to be met during the elevation, it was necessary to build the retaining walls on the west side first. In order to do this and maintain traffic, a temporary track was laid east of the north-bound track, between Brandywine Bridge and Todds Cut, and the north-bound trains were transferred to it. The abandoned north-bound track was then moved eastwardly about 4 ft. to give room to allow the building of the bridge abutments, of sufficient length to carry two tracks at the new grade, and then the south-bound trains were transferred to it. A standard single-track trestle was built on the line of No. 3 track, and a crib about 10 ft. high built along the foot of the trestle to hold the earth filling for No. 4 track from falling on

or obstructing south-bound trains. Upon the completion of the masonry for Nos. 3 and 4 tracks north of Brandywine Creek, work was started on the new bridge over the Brandywine.

As the site of the new bridge was practically the same as the old, it was necessary to build a temporary bridge to one side to carry the traffic. The temporary bridge was designed to use one span and the draw of the old bridge and a pile trestle at each end. After the pile center and trestle were built, the draw of the old bridge and the one span were shifted between trains to the new location in the temporary bridge, and the traffic placed thereon and work on the new bridge begun. As soon as the pivot pier was completed, the north and south abutments built wide enough to carry two tracks, and the rest pier carried up to a height of about 3 feet above high-water mark, the work of erecting the new steel work for the fixed span and the north half of the draw was begun. The rest pier could not be carried any higher than before mentioned at this time, on account of the temporary draw, as when the draw was opened, it rested over the site of the new rest pier. When this steel work was in place, arrangements were made to close the old draw to navigation, excepting such vessels or barges as could pass under the draw while closed. A small tug was placed on the up-stream side of the bridge to tow the barges to and from the dock, about one-half mile further up-stream, the barges being the only vessels wanting to go beyond the old bridge while the draw was closed. Upon closing the draw, the masonry for the rest pier was rushed to completion, and then the south half of the new draw erected. This was done rapidly, by having each pair of girders to carry one track already riveted up. They were loaded on flat cars and blocked up to the proper elevation, so that when ready to place, all that was necessary was to bring them to the bridge site by special movement between trains, and then, by means of stationary engines placed on shore and lines attached to the girders, to slide them laterally over well-greased rails to place. This work was done between trains, and occupied about forty-five minutes' time to each pair of girders. The draw was then riveted up; the machinery was placed and put into service as soon as possible. Then the old draw and trestle were removed and ordinary traffic on the Creek resumed. The old draw remained closed for a period of about four weeks.

The only thing out of the ordinary in the superstructure of the new draw is the fact that it is a deck girder of the fish-belly type, carrying three tracks, and having a total length of 164 ft., and giving a clear

channel of 59 ft. It is operated by a gasoline engine of 30 H.P., placed to one side of and below the tracks. The center is the same type as is used in all drawbridges on the Pennsylvania system. The draw weighs 965,937 pounds, the fixed span 282,866 pounds—a total of 1,248,803 pounds.

The construction of the bridge presented no unusual obstacles. The work was carried on during the winter months, and on account of three freshets in as many months caused considerable trouble to the contractors, one ice freshet carrying out the cofferdam for the center pier just when ready to pump out and place the concrete, the high water also endangering the temporary bridge. For building the pivot pier, the framework for an open caisson was built on shore. When it was ready for launching, a number of empty oil barrels were placed between the middle and lower rings of the caisson to provide sufficient buoyancy, and after the caisson was launched, it was floated into place and the barrels removed. Wakefield sheet piling was then driven to solid rock around the periphery of the caisson, after which clay puddle was placed around the outside, to make the bottom of the caisson water-tight. On account of the strong tide in the Creek, the rock bottom was practically bare, and a layer of clay was first placed on the bottom, and then canvas on top of this and more clay on top of the canvas, in order to keep it in place. The idea of the canvas was that when the caisson was pumped out, in case the water started to find its way through the bottom along the foot of the sheet piling, it would carry the canvas with the clay into the openings, thereby stopping them up.

During the construction of the bridge the retaining walls on the west side between Brandywine Bridge and Fourth Street were completed and part of the bridge at Seventh Street. A double-track trestle was built from the Bridge to Seventh Street and a single-track trestle from Seventh Street to Fourth Street for a rundown to the old grade at Fourth Street. Filling between the trestle and the retaining wall was made for No. 4 track, intended to serve the freight yard on the completion of the work, and was used for a rundown for the south-bound trains. This rundown was placed in service for both north-bound and south-bound trains when the trains began using the new bridge over the Brandywine. When the retaining wall on the east side between Brandywine Bridge and Fourth Street and Seventh, Fourth, and Third bridges were completed, a single-track trestle on line of No. 2 track was built at the new grade between Seventh and Fourth Streets, and a

rundown made from the high grade at Third Street, to the old grade at Front Street. A temporary trestle was also built outside of the east retaining wall, from the high grade at Fourth Street down to the old grade at Seventh Street. This was done to take care of the traffic to the manufacturing plants on the east side, between Fourth Street and the Brandywine Bridge. This trestle, being built to the permanent grade and location, was afterward filled in and the stringers removed.

As soon as the north-bound trains used the new line between Front Street and the Brandywine Bridge, the temporary rundown for north-bound trains between Fourth and Seventh Streets (which occupied the site of the middle retaining wall between Fourth and Seventh Streets) was removed and work started to complete this wall. This had to be done before the south-bound trains could use the high grade between Third and Seventh Streets, and the temporary rundown from Third to Front Street. This work took considerable time, as the tracks of the south-bound trains on the rundown were only a few feet away from the face of the wall, and the north-bound tracks on the new high grade were close to the back of the wall. This left little space for the contractors to work in, and it took about three months' time to build this wall. When finished, the south-bound trains between Seventh and Front Streets were transferred to the new high grade, the same as the north-bound trains were then using. At the same time work on the southern section was carried on from Orange Street to the south end, near the P. & R. and B. & O. crossing.

Traffic on this section was maintained in the same manner as in the section from the Brandywine to Todds Cut. It was found that it would be necessary to go to a depth of from 15 to 30 ft. to obtain a good foundation through the west yard, as at a depth of about 6 to 8 ft. a very soft stratum, 5 to 10 ft. in thickness, of black clay and mud was encountered. It was decided to build a three-track arch viaduct, as costing less, and easier to build, than two side retaining walls, for a distance of about 2200 feet, extending from the B. & O. crossing to Liberty Street. This part could also be finished at once without any further shifting of tracks. The rest of the section, north and south of the viaduct, consisted of two parallel retaining walls, similar to the other sections.

The viaduct consisted of two series of arches, separated by a plate girder bridge at Beech Street cutting the viaduct nearly in half, there being twenty arches south of, and twenty-three arches north of, Beech Street. The arches are of 41-foot span, rise 8 feet, and the rings are of

brick, with a depth of 34 to 35 inches. The foundations of the piers and abutments are of rubble or concrete up to the foundation offset. Sandstone skewbacks were used, and between the skewbacks and foundation offset the piers were laid with coursed ashler, the abutments being coursed ashler, as they also acted as abutments for the steel bridges.

The viaduct presented no unusual difficulties to construct, except that much care was required in building the foundations for the piers and abutments, the temporary main tracks of the P. B. & W. R. R. being only about 6 feet away from the east side, and the yard tracks of the Philadelphia & Reading (old Wilmington & Northern) being the same distance away on the west side.

In order to protect the masonry, a waterproof covering was laid over the top of the backing and spandrel walls. This was done by finishing the backing of arches with a thin layer of cement, making a practically smooth surface, on which were laid five layers of Hydrex felt, laid shingle fashion across the viaduct, with about 7-inch lap, each layer well mopped with hot asphalt or Hydrex compound, the whole afterward thoroughly mopped. This made an elastic and tight covering of about $\frac{5}{16}$ inch thickness, and on top of it was placed about one inch of cement mortar. The felt at the sides was carried up and flashed into the joint between the coping and string course to the depth of about one inch, and on the vertical side walls and on the top of the string course were placed hard brick laid in cement. This covering was to prevent the felt from being punctured by the ballast and also to keep the felt from slipping on the side walls. Drainage was obtained by placing two 4-inch cast-iron pipes over the piers on the center line of the viaduct.

Work on the section between Justison and West Streets was stopped on account of injunction proceedings lasting for about two years. When much of the work south of Madison Street was completed, it was desired to make use of that part of the elevated, pending the decision on the injunction suits, so a temporary rundown with a grade of 2.8 per cent. was built between Madison and Justison Streets. Southbound traffic was first placed on this section, and then the trestle for the north-bound was built and placed in service about three weeks later. All the work south of Madison Street was then completed.

With the work of the Front Street crossing completed and considerable work done between Front and Walnut Streets, it was decided late in 1905 to begin work on the new passenger station. A temporary frame passenger station was built east of the old surface tracks on

Water Street, and as soon as placed in service, the old station was torn down and foundations for the new station begun. The west half of the station was then built, together with a four-track steel viaduct from French to Walnut, this viaduct forming part of the station. The space underneath is occupied by the baggage-room, express, packing-room, telegraph offices, etc. The ticket office is on the street floor along Front Street, while the south-bound waiting-rooms are placed on the second or train floor, Front Street.

With the completion of this part of the station and enough of the Poplar, Front, and Lombard Streets bridge to carry No. 4 track, the tracks on the rundown at Madison Street were shifted one track to allow the construction of a trestle at the high grade on line of No. 4 track between Madison and Justison Streets, and south-bound trains were placed on this track. This gave the use of the elevated for south-bound trains from the north end at Todds Cut to the south end at "X A" tower, south of the B. & O. crossing, and also use of the new passenger station. Work was then pushed to carry the north-bound across Front Street bridge on No. 3 track and to build a high-grade trestle between Madison and Justison Streets on line of No. 3 track. As soon as this was done, the north-bound trains were placed on this track and the temporary station and the passenger traffic on the remaining portion of the old line abandoned. The temporary station was then torn down and work started on the other half of the station. Work was also started to complete the balance of Poplar, Front, and Lombard Streets bridge, and that part remaining to be done between Tatnall and Madison Streets.

The superstructure of the bridges over the streets south of Seventh Street are of steel, with solid floors made of angles and plates to form a trough section running at right angles to the main girder. These were filled with concrete to a depth of 1 in. to 3 in. over the rivet heads, the difference in thickness being given to obtain the necessary drainage. In ordinary cases of a short bridge, the drainage is carried back over the back walls, but where the bridge is over 50 or 60 feet in length, 4-inch pipes are placed near the columns along the curbline, and the water carried off through them to the street. The concrete was carried up the side of the girder to about 9 in. above the surface of the concrete floor, and then Hydrex felt placed on it, as described on the arches before mentioned. The finish on top of this consisted of a one-half inch layer of sand, and a layer of hard brick well grouted on top of the sand. Around the drains were placed, after the first layer of

felt paper had been applied, an apron of sheet lead about 24 in. square, with a shoulder let into the drain-pipe. The rest of the felt was then laid over it. This has produced a very good and water-tight joint and has given good satisfaction. The following approximate figures may give an idea of the size of the operation, viz.:

Filling	345,400 cu. yds.
Excavation	130,000 cu. yds.
Masonry of all kinds, except brick	164,200 cu. yds.
Brick arch masonry	19,600 cu. yds.
Waterproofing arches	84,100 sq. ft.
Waterproofing bridges	42,000 sq. ft.
Iron used in bridges	10,700,000 lbs.

Frame for Caisson.

PAPER No. 1061.

WATERPROOFING—AN ENGINEERING PROBLEM.

MYRON H. LEWIS.

Read June 6, 1908.

WATERPROOFING is an industry which, in its relation to structural engineering, is deserving of a more prominent place in our considerations than has hitherto been accorded it. Architects, engineers, contractors, and builders in general have been slow to recognize the beneficent influence of a well-designed and executed system of waterproofing upon the healthfulness, durability, and esthetic character of our modern structures, as well as upon the comfort of their occupants.

It is only within the past few years that the increase in subsurface construction and the consumption of cement in the building industry have given a lively impetus to the development of waterproofing along scientific lines, and that the subject has been taken up by prominent technical bodies. The interest thus awakened, however, is advancing with a steadiness that leads us to hope for much more rapid progress in the future.

We must, in the beginning, endeavor to define our subject, so that its limits will be clearly understood, a necessary precaution since many writers have fallen into the error of assuming that the particular method which they have to exploit covers the entire field. In its broad sense, "waterproofing," as its name implies, is the rendering of materials or of structures immune to the action of water. "Waterproofing engineering," then, is that branch of general engineering activity which is devoted particularly to the means of protecting structures against the ravages of water in its discomforting or destructive forms. It includes not merely the methods of treating various substructural conditions, and it does not stop in treating concrete to make the latter impermeable, as some writers on those topics try to convince us. It includes, as well, the treatment of the materials themselves as of the structures composed therefrom before or after erection, above or below ground, or in water. So also does its scope include a discovery of the causes of, and the remedies for, objectionable conditions in buildings

already erected, and the prevention of decay and disintegration of structures and structural materials.

Taking waterproofing in this broad sense we must realize that its universal application must confer a boon upon humanity, since its function is to greatly increase the life of those structures in which it is judiciously used, and, what is of more importance, to secure to the dwellers therein immunity from the diseases which are fostered or spread by damp, clammy walls and the unwholesome conditions incident thereto.

It is scarcely necessary to dwell on the sanitary aspect of the question, since it is a fundamental principle of hygiene that dry habitations are necessary if we would enjoy the normal degree of health.

We paint our steel structures to prevent corrosion, but do we exercise a like care in seeking to protect the vast quantities of steel that enter the concrete of our modern structures?

We paint the outside of our frame dwellings for purposes of durability as well as beauty; but do we realize that for a trifling expense we can so treat the entire timber work of such dwellings as to effectually retard its decay?

We take the precaution of draining our cellars into sewers; but, with a singular inconsistency, do we not often fail to protect them against becoming moisture soaked and unsanitary?

We expend large sums in the construction of costly reservoirs, tanks, and dams, and frequently fail to take the precaution to conserve the water thus expensively stored, as might be done by providing a watertight enclosure, thus guarding at the same time against either a contaminating inflow or a wasteful outflow.

We erect stately mansions of artistic design, costly material, and skilled workmanship, and before many years have passed their exterior beauty is defaced by stains or by the unsightly efflorescence, all of which is easily preventable if the simple expedient of waterproofing is adopted while the building is in the early stages of construction.

An impressive illustration of the value of intelligent waterproofing is to be found in the modernly constructed buildings in the city of New Orleans, in which are being installed basements to a depth of 12 feet or more, where once this would have been considered impossible owing to its water-bearing soil and the absence of an adequate sewer system.

We install expensive machinery in buildings equally expensive, and too frequently this machinery becomes so clogged with rust, or in the case of electrical machinery becomes short-circuited, as to render its

delicate parts unfit for use, so that its overhauling becomes a matter of necessity—even before it has ever served its purpose. Since rust is a result of moisture, and moisture may also be the cause of short-circuiting, it follows that in a moisture-proof building no such conditions could occur.

We design and install elaborate sewer systems, the result of much study and deliberation, into which skilled engineers put their best thought; and we spend thousands of dollars in the providing of efficient sewage disposal plants; but we often neglect to make the sewers watertight, with the result that the pumping and disposal plants are burdened with the handling of ground water, which in many cases equals the entire volume of sewage flow, increasing the maintenance cost perhaps 25 per cent. or more.

Figures bearing on this subject have been compiled by Mr. George T. Hammond, Member of the American Society, who is in charge of the sewer system of Brooklyn, N. Y.

We go to great expense in constructing refrigerating plants, but through defective and leaky walls moisture finds its way, thus raising the temperature of the cooling rooms after every effort has been made in other directions to keep it down.

We put up expensive concrete superstructures, and it too often happens that lack of provision for waterproofing, or a defective system, causes the building to be unfit for occupancy and entails upon the owner serious financial losses.

We put up our buildings with all possible speed in the hope of saving time and money, and before the walls have been given time to lose the large quantities of water stored up by rains or by water used during the construction period, we apply our paint to the outside and plaster to the inside, only to find that from the pernicious activity of moisture first one and then the other begins to loosen up, peel, and go to pieces.

Often we take proper precautions to prepare our specifications with a view to securing perfectly dry structures, and through a false economy in the effort to select the lowest bids, or through inadequate supervision, we find the work which we expected to be perfect turns out to be leaky and troublesome. Therefore, excavations must be reopened, and the origin of the troublesome water traced to its hidden, and what sometimes seems undiscoverable, source.

Other cases might be cited where conditions exist which have in the past caused much trouble, inconvenience, and expense. They are by no means visionary, but are gathered from actual experience, and the

precise structures furnishing the examples quoted can be pointed out. If such conditions were the exception, and were met with but occasionally, we might be inclined to pass them by with an indifferent remark, but their continual recurrence bears out the assertion made at the outset, that the advantages and benefits accruing from waterproofing are not sufficiently understood nor appreciated by those who have in charge the planning and designing of construction work.

Let us consider for a moment why this should be so. First, there has until recently been lacking in the building industry a publicity medium through which these features of construction work—benefits or dangers—could be pointed out by those who, because of their practical experience, are competent to observe and explain.

Secondly, because architects and engineers having often false impressions as to the immunity of structures from water penetration, and with a view of keeping down the cost, have chosen to look upon the important item of waterproofing as a superfluity.

Thirdly, because those engaged in the waterproofing business are usually practical men with but little desire to give to the public the benefit of their experience.

Fourth, and not least, because of the unfortunately narrow policy hitherto followed by the latter or by a large proportion of them. This policy has been not only narrow, but obstructive in its results—narrow, because each concern has arrogated to itself a monopoly of the only successful methods of waterproofing known, and not content with this, has taken the untenable position of disparaging and even denouncing as worthless the methods and materials of competitors. Narrow, also, because some of them have put forward their own materials and methods as infallible cures for all possible conditions, and make other extravagant and impossible claims, which, instead of inspiring confidence and attracting support, are rather calculated to awaken suspicion and distrust in the mind of the intelligent and critical purchaser.

We have long been accustomed to see printed in public advertisements that "This compound is the only permanent and efficient waterproofing material known." And we have seen this statement so often that skepticism has developed into downright unbelief. We all realize that no individual firm enjoys a monopoly of the materials with which nature has supplied us, and that to such a firm only cannot be restricted the power to produce a material that is permanent and efficient. Such a policy can only react upon the industry in general by

causing a loss of confidence in the entire scheme, and, as a consequence, bring confusion and loss upon the people who had hoped to benefit by it.

At one meeting where there were five different papers read by as many representatives of waterproofing processes, each claimed to be the one and only correct exponent of what we may call waterproofing engineering. One of the ablest of these was by Mr. Edw. W. De Knight, whose very interesting writings most of you have read from time to time; but as the advocate of the "membrane method," his papers are exclusively devoted to an exposition of this one system; and his term "waterproof engineering," applied to this method alone, is a misnomer.

While the "membrane method," or the enclosing of a substructure in a bituminous stratum, is possessed of greatest practical efficiency, Mr. De Knight refuses to recognize in his papers that there are conditions in which the application of his method might be wholly impracticable from an economical standpoint. In severely condemning the use of surface coatings or cement waterproofing compounds he ignores the stubborn fact that a building already in place, which proves leaky below ground, cannot be remedied by the membranous method, excepting at a comparatively exorbitant expense.

And so it is with the exponents of the asphaltic mastic waterproofing for universal use, when they fail to limit the use of such methods to their proper field.

So also with the manufacturers of waterproof paints, who, instead of wisely limiting their recommendations for the uses of those paints to conditions where they have their chief value, recklessly undertake to exploit them for indiscriminate and often most inapplicable purposes.

In this class, also, we must include the manufacturers of cement waterproofing compounds, materials which in certain conditions are unexcelled, but which may be misapplied to the great vexation, annoyance, and loss of the user.

Impartial advocates of scientific waterproofing, those not interested in any special material or its advancement, cannot fail to admit that there is a good deal of merit in each of the methods which have been successfully employed in the past. Practical common sense compels us to acknowledge that there is no sure and universal remedy for all conditions, and we realize that we must study waterproofing problems with the same scientifically observing eye with which we study all other engineering problems, and accept only that method of treatment which is best suited to individual conditions.

As technical investigators, we should not depend entirely upon what

we read in trade literature, where we find glowing eulogiums of certain products. We must weigh the facts, and then decide for ourselves.

The mind of the engineer and architect is trained to investigate—to suit the means to the end, the remedy to the conditions, and we must follow the same procedure here as we do elsewhere; this being done, mistakes and failures in waterproofing will become increasingly rare.

This earnest appeal is made because the need of scientific waterproofing is daily on the increase; while, on the other hand, many are deterred from availing themselves of its possible benefits because of the conflicting statements previously referred to.

Now, let us ask, how can these conditions be corrected?

First, by eliminating the causes above outlined.

Secondly, by systematic investigations undertaken by technical bodies for increasing our knowledge of the subject. A few are now in progress. The United States Government is now making tests at St. Louis; the American Society for Testing Materials has a waterproofing committee; the National Association of Cement Users has the subject in hand; and we trust that when their reports are ready a great deal of information will be available.

One of the principal difficulties encountered in committee work of technical societies is the tendency to rely too much on laboratory tests, particularly small scale tests. The examination of waterproofing systems in the field should have as much influence in determining their efficiency as the laboratory tests, and each should supplement the other. While we may be deciding the fate of a material adversely because of the negative character of the tests, we may have the pleasure of seeing the same process applied on a large scale in the field with results which prove its efficiency. This has happened more than once. Conversely, what has shown up admirably in the laboratory may, in the safer test of actual practice, prove entirely inadequate.

The Design of Waterproofing Systems.

A thorough understanding of the correct designing of waterproofing systems presupposes an understanding of the laws of physics and of chemistry. The designer should be in a measure familiar with the physical and chemical nature of the materials he proposes to employ, and their effect upon the structures. He must be familiar with the calculation of hydrostatic pressures, so that he can guard against the making of floors and walls too thin for safety or too thick for economy. He must be familiar with the influence of subsurface and general

atmospheric conditions on the materials he employs, so that asphalt will not be used where coal-tar will serve the conditions better, nor vice versâ. And so the designer should be conversant with the whole gamut of possibilities; his mind must be ceaselessly on the watch for causes and effects; picking out the necessities of the problem, providing for them, and fitting in the details to make a complete whole.

Let us assume for a moment that we are called in to design the waterproofing of some representative building. It is customary on the part of many architects merely to follow the methods of applying a certain number of coats of asphalt or felt and to stop there; or to patch up specifications based on some other structural work. If we are to handle the problem rationally, we must approach it in the same way as we approach any other problem in design.

Let us consider first the substructure of the building. From the necessary data obtained to determine upon the character of the foundations we learn more or less accurately the nature of the underlying materials; and it is of the utmost importance that we take this fully into consideration in the designing of the waterproofing system. If the ground is rocky, containing no seams, or is dry earth free from springs or subterranean streams, our difficulties are immensely lessened, and we can proceed to design a continuous external shield of bituminous materials, or an internal lining of waterproof cement mortar, as economy and other conditions may dictate. Should, however, the substrata contain water-bearing or saturated earth, we must provide for drainage during and possibly after construction, to relieve the pressure against the structure as much as possible. We must also determine the amount of hydrostatic pressure that may develop against the walls and floor.

Bituminous shields or membranes, having of themselves no great strength, must be weighted down by masonry or otherwise protected so as to prevent their displacement by the external pressure. The extent of the pressure to be resisted will in great measure determine the thickness of the waterproofing stratum to be employed. The character of the ground water coming in contact with the waterproofing must be taken into account, for if acids, sewage, gases, and other foreign matter are present, the materials for waterproofing should be selected with a view to their power of resistance to such influences.

Only a short time ago, one of the modern office palaces in New York, constructed in the most lavish style with unlimited means, suffered from a condition of this kind. Situated not far from the shore, with

its sub-basement 14 feet below the tide level, almost every precaution was taken to obtain a substructure that would be bone dry. No expense was spared, and with just pride the contractor pointed to the work as one of the greatest waterproofing achievements of the age.

In the sub-basement of this building was installed expensive machinery to heat and light the building and provide power for the elevators. But before the lapse of many months it was found that water had begun to come in at various points along the walls and floor, and the conditions soon became so annoying as well as damaging that investigation had to be made with a view of correcting the trouble. It was thought at first that the enormous weight of the columns had punctured the waterproofing, thus causing the leaks; and while this was a probable theory, further examination disclosed the fact that on the plastering, along one section of the wall, there appeared great black blotches of dampness. This was overrun with vermin, converting the walls into a filthy and hideous sight. We have never known that a clean concrete wall supported animal life, and some animal or vegetable material must have been present upon which they could germinate and feed. Not far from the building was a large sewer outlet, and adjoining the foundation were the street sewers, through the linings of which the sewage no doubt readily filtered.

The material used in treating this foundation was evidently being attacked by the constituents of the sewage, under which it finally broke down, and the difficulty was remedied by the application of an interior cement mortar plaster, but only at great expense.

The mistake of having failed to take all the conditions into account in making the plans for the structure in question was the cause of the trouble. The same materials used here have given entirely satisfactory results in other localities, but they were not proof against this action. The action of sewage on bituminous materials is as yet a very unsettled question. When this case came to the writer's attention he addressed letters to the leading authorities on the subject, but no actual tests along this line had been made, and the answers were very indefinite. It is hoped, however, that the near future will reveal some interesting facts in this direction, as we are now undertaking some tests on bituminous materials, by suspending them in the manholes of the Brooklyn City sewers. This subject will become of increasing importance as the waterproofing of sewers comes into general use.

These facts are presented to indicate how careful the designer must be to foresee and forestall any possible injury to his waterproofing.

Possible effects of frost or illuminating gases, of settlement or vibration, and other parallel conditions must be considered with a view of using the right material in the right place. In many instances various materials or methods may be employed with equally good results, and then, of course, economical considerations are the controlling features.

It is for the engineer or architect to decide what shall be used, and it is to them that the owner looks for results. We must not try to evade our responsibility by shifting the blame to the contractor or the manufacturer.

Let us now consider the superstructure of the building. How shall we dampproof it? We must continue our investigations along similar lines. Shall we use the method of furring and lathing, or clay tile, or metal lath, or wood? Or shall we apply our plaster directly on the wall? Shall we waterproof from the exterior, or on the interior surface? If the building is of brick, we can safely waterproof it on the interior, and apply the plaster without fear of trouble if the work is properly done. If the building is of concrete, we are not so sure of the adhesion of the plaster to the waterproofing film, for experience in this line has been too varied to allow us at this stage to speak decisively. The smoothness of the concrete surface militates against this method somewhat, since there seems no key for the bonding of the plaster, which is not the case in the large joint area brick or stone wall. We may provide for the waterproofing, first, by serrating the concrete, or pitting or rough finishing the surface; second, by waterproofing from the outside; third, by the "Integral" method, or the addition of a compound to the cement, in which case the waterproofing compound becomes an integral part of the mass. The second named method, while efficient, requires, of course, periodic renewal, and while it is practically the best method of dampproofing in existing structures, it is not as permanent as interior dampproofing when properly done. We will refer to the third method later.

Let us now consider that our plans and specifications are completed and we are prepared to begin work. Do we look after our waterproofing as we do after other details? Usually not. How many of our inspectors can tell whether the walls are in proper condition to receive the waterproofings? How many can tell whether the waterproofing materials specified have been supplied, or these substituted by a cheaper material? All tars, asphalts, and black paints look alike, and to many are one and the same thing; and for lack of competent inspection the best laid plans may be brought to naught.

Why is it that rank conditions are often discovered in buildings where the plans and specifications have been all that they should be? Because the work is improperly done—the material defective. Good work not properly done, or even injured. Conditions unsuited to the work. After the building is in place and leaks are discovered, the architect "puts it up" to the contractor; the latter, to the architect's inspector; so that there is a general shifting of responsibility. The result is a loss to all concerned in money and in reputation.

Before we allow cement to go into the work we generally test it ourselves or have it sent to the laboratory for testing. We examine our brick or stone to see that they are up to our standard. We often go to unnecessary refinement in examining our sand and stone for concrete; but how often do we take the trouble to find out whether we are getting the waterproofing we are paying for? Why should we not test these materials as they come on the job, in the same way that we test our other construction materials? Why pay for asphalts when we are getting oil substitutes? Why accept soap or powdered lime when we are buying waterproofing compounds?

So many failures have been reported from the application of waterproofing when the walls were too wet or too rough, and from the failure to protect the waterproofing from injury due to unnecessary exposure, back-filling, or other causes, that a competent inspector should be always on the work, and no work done in his absence.

Defective waterproofing is almost worse than no waterproofing. It is costly to repair, especially when, on the exterior of the foundation walls, the origin and source of the trouble can with difficulty be traced. It follows, therefore, that the best is the cheapest. It costs ten times as much to repair a bad job as to do it right in the first place. All of which goes to show that it behooves us when asking for bids not to look with favor upon those figures which are ridiculously low.

This has often proved a disastrous policy when unforeseen difficulties are encountered, and this is a common occurrence in subsurface work. All the more reason why we should have proper and adequate inspection. Responsibility of the bidder in contract work is just as important as the amount of the bid.

In a few words we can sum up the subject of waterproofing as an engineering problem.

1. Careful investigation.
2. Adequate design.
3. Suitable materials.

4. Careful construction.
5. Favorable conditions.
6. Intelligent inspection.
7. Systematic tests of material.
8. Responsibility of contractor.

With all these given careful attention, waterproofing of our structures becomes as certain and permanent as we may expect it to be.

With this general survey of waterproofing as an engineering problem let us proceed to a consideration of some of the more intimate details of the question. Our structures are exposed to trying conditions with which the engineer is, as a rule, very familiar, although the connection between these conditions and the desirability of waterproofing is often lost sight of. These conditions include action of atmospheric agencies, such as wind, expansion, contraction, absorption, chemical action, etc.

Building materials are, as a rule, quite porous, and ordinary mortar in which our masonry is laid is very highly so. The variations in porosity are so great that no table can be taken as conclusive. Just at the present time the engineering profession is paying a great deal of attention to the porosity of concrete, and the technical papers are full of articles on impervious concrete. Those who have worked in the laboratories claim that concrete can be made impervious without special treatment. Practical concrete workers, on the other hand, have found this to be rarely the case, even when the utmost care is exercised in mixing and laying. There is no doubt that concrete can be mixed in the field so that a nearly impervious mass can be obtained, but it is questionable whether the extra trouble and amount of cement required to do this do not make the process less desirable than the use of a good waterproofing compound.

Furthermore, we must draw a distinction between an impervious concrete and a non-absorbent concrete. A concrete may be practically impervious to water under pressure, and yet, through the slow but persistent action of capillarity, dampness may penetrate it through many feet. This distinction is singularly overlooked by even leading writers and practitioners, and yet it is an all-important detail in the concrete block or reinforced concrete building superstructure. For this class of work imperviousness is not enough. We should have non-absorbency, water-shedding, or antihydrous concrete, or, as it is appropriately called, "capillary negative," in contradistinction to ordinary concrete, which absorbs water, and is, therefore, "capillary positive."

The subject of capillarity is very little understood by the ordinary worker in concrete, and its power is not comprehended.

Let us for a moment go back to our physics.

Capillary Attraction and Repulsion.

The action of capillarity is best explained by referring to the action of the liquid in fine tubes. Liquids, when brought in contact with solids, are either repelled or attracted. Those liquids which are attracted to the material in the tube, rise, while the others are depressed. The amount of rise or depression depends upon the diameter of the tube and the character of the liquid. The finer the tube, the greater the capillary attraction. Thus, in a converging tube, water is drawn to the narrow end, while a capillary negative material is drawn to the wide end. Cracks in masonry walls may be considered as a succession of such tubes converging into the interior to which the water is drawn.

Now, if through the addition of a waterproofing compound to our concrete work, or the impregnation of our masonry surfaces with a capillary negative material, we destroy the absorptive power of the wall, then we may rest secure as to the dryness of the structure, provided, of course, that the material is stable in character and that it has been properly applied.

The architect and engineer realize, as a rule, the important part that temperature changes play in the durability of our structures; but it is difficult to impress upon the lay mind that the distortion due to this cause—the expansion or shrinkage resulting from heat—is of much consequence. In order to bring out these facts Table 1 has been prepared, showing the changes in dimensions for a change of temperature of 100° F. Such a change is common in our climate.

As the volume increases with the cube of the length we notice that the volumetric changes appear very large. Thus, in the case of plaster the increase is 2.7 cu. ft. in a 10 ft. cube. When we realize that in order to produce these changes enormous mechanical power must be applied, we can understand the strain induced in our structures when, owing to rigidity, they are not free to move. Of course, such masses are obtained only in the case of dams and similar structures, and the results are evidenced by cracks.

In proportioning the foundations of buildings it adds to the life of the waterproofing to minimize, as much as possible, disturbance through settlement.

This can be done by proper reinforcement and great economy in

material results as well. With a large head of water on the foundation, a concrete floor unreinforced, must be very heavy to counteract the pressure, but by properly reinforcing the cellar floor to the walls and columns, the entire weight of the superstructure is brought into play in resisting the water pressure, and the thickness of the floor may be greatly reduced.

In using bituminous waterproofing, one of the important considerations is to have a good surface upon which to apply it. If this is too rough or ragged, a good hold cannot be obtained and air pockets are formed which eventually fill up with water.

The surface should also be clean and dry. It is a difficult thing to place the material on a wall reeking with water, and proper drainage should be maintained. If this is not had, the material is liable to be pressed off the wall before the supporting masonry is placed.

Every detail of the work requires careful attention, and unless conscientious workers are employed, materials may be wasted and be of no benefit. The mopping of the materials should be done quickly, uniformly, and thoroughly, and while it is at the proper temperature. The joints in the felt should be well broken and cemented together. Good work cannot be done in very cold weather as the cold air chills the bitumen too quickly.

It is of utmost importance also that there be not at any point a break in the continuity of the work. Disregard of this essential has been the cause of many failures. One of the difficulties in securing continuity is encountered in joining of new to old work. The laps become covered with dirt, cement mortar, water, etc. Before any new work is added, the joint should be thoroughly cleaned and coated with the cementing material. It is here that a good inspector is needed, as workmen are often tempted to neglect this precaution. The application of the fabric and the cement does not by any means complete the work. The placing of the masonry against the waterproofing must receive careful attention on the part of the inspector. Innumerable good jobs have been injured—even ruined—by being punctured during this operation, especially when the backing is concrete. Sharp projecting stones coming in contact with a film will break a hole through the latter which will admit water, and the source of this leak will be extremely difficult to discover. It is always advisable where backfilling or concrete comes in immediate contact with the waterproofing, to protect the latter with a one-inch coat of cement mortar.

It frequently happens that other work, such as plumbing, must be

installed after the waterproofing has been set in place, and not infrequently the plumbers, or other workmen who have but little conception of the importance of preserving the waterproofing intact, make incisions in the film for the insertion of pipes through walls, and neglect to make the proper repairs to such breaks. Of course, the consequence of this recklessness is that leaks appear, and a division of responsibility among the various contractors. The specifications should clearly provide against any tampering with the waterproofing without the direct knowledge of the architect or others in authority.

Reservoirs may be waterproofed in substantially the same way as walls, the principal difference being that the coating is placed near the water surface. The large area exposed to temperature changes, particularly during construction, makes it advisable to lay the lining in sections (as shown here), and fill the joints with a bituminous cementing material.

Treating the concrete *en masse* by the incorporation of a waterproofing compound is herein called for convenience the "integral method," as the compound is supposed to become an integral part of the structure. In this method the compounds usually employed are, first, liquids to be added to the water used in tempering the cement, and these are usually some form of chloride of lime, sulphates of aluminum, and oil emulsions; second, Sylvester soap and alum mixtures—the powdered alum added to the cement, and the soap solution to the water; and third, such materials as hydrated lime and metallic stearates, which are usually chloride of lime in combination with stearic acid.

The liquid compounds impart waterproofness by the formation of a gelatinous coating about the cement particles. The soap and alum mixture deposits aluminum silicates in the voids. The hydrated lime acts as a void-filler, and the metallic stearates act as void-fillers, but they also possess in a marked degree the repelling action to water before referred to. Each one of these materials possesses some good qualities—all of them reducing largely the permeability of the concrete. But for lack of long time tests definite statement as to whether their waterproofing properties are permanent cannot be made. Some of the stearic compounds have been used in buildings that are now five years old, and as yet there is no symptom shown of the diminution in their water-repelling property.

The integral method of waterproofing is particularly useful in the superstructures of buildings, and to the remedying of damp conditions in substructures already erected.

Of all the dry compounds recommended, those which seem to be most in favor with the consumers at the present time are the metallic stearates. This is because they possess not only the void-filling property of hydrated lime, but also destroy the water-absorbing quality of the treated concrete, as stated before.

When first introduced, it was feared that they would seriously injure the strength of the concrete, but experience has proved that this apprehension was groundless.

Table 2 shows tests of ordinary Portland cement and Hydratite Portland cement, showing effect of the addition of Hydratite (Prof. Black). These tests show the effect of the compound on the cement. They are not of sufficient duration to justify conclusive opinions. The tensile tests were made in the usual way. The adhesion test was made by filling half a briquette mold, allowing this to set hard, then filling the remaining half. The conclusions to be drawn are:

1. The set is somewhat retarded.
2. The compound decreases the strength of cement mortar.
3. The compound increases the strength of cement mortar.
4. The adhesive power of old to new work is increased.

Professor Black was not aware of the identity of the materials, the latter having been simply labeled "No. 1, No. 2," etc.

Table 3 shows tensile and permeability tests on cement treated with Hydratite, Meduse, Aquarex, and Maumee (one week to six months) (Spackman Eng. Co.).

One of the leading manufacturers has furnished this series of long-time tests, made by the Spackman Engineering Company of Philadelphia. Five materials are included in this test, and the range is six months' duration. All were made on a 1–5 mortar, and they do not show in any of the tests a material decrease of strength. The laboratory received the samples as "Nos. 1, 2, 3, 4, 5," without any other identifying mark.

A great deal of important work has been done by using a cement waterproofing compound, and some of the largest buildings in New York city have been treated in this way. The city Investing Building and the Hudson Terminal Building furnish the highest example of this type of waterproofing. The plan usually followed is to apply to the inner surface of the substructural walls a continuous coat, $\frac{5}{8}''$ thick, of waterproofed cement mortar plaster, and the same plaster 1 to 2 on the floor. To obtain a good result the greatest care must be exercised in procuring a rich and uniform plaster, a perfect bond of the plaster to

the wall, and—here as always—the fundamental principle of complete continuity must be rigidly enforced, as well as careful protection while the material is setting up.

All this requires assiduous, painstaking work. When properly done, however, it repays the care exercised, and one of its advantages is that it is always in view and can be readily repaired. Besides which, it forms in itself a finish for wall and floor surfaces. It obviates the necessity of excavating and of supporting walls, which are indispensable in the bituminous method.

One of the difficult problems to be encountered in this work is the bonding of old to new concrete. This can be effected by scratching and hacking the old surface to remove the skin glaze, and by applying a solution of muriatic acid in water, which should be followed by a thorough washing off with water to remove the acid. No work should be placed on the walls thus treated until a competent inspector has passed on its condition. When the surface has been properly prepared, the adhesion is so strong that the plaster can only with the greatest difficulty be separated from the wall.

If there is a water pressure behind the wall and it is leaking badly, recourse must be had to temporary drainage or "bleeding." The water may be led to a temporary sump, and the latter can be sealed after the waterproofing is sufficiently set up.

The writer has been asked several times about the value of collodial clay for waterproofing, and is of the opinion that it does not possess the properties we are looking for. It is difficult to obtain. It requires to be pulverized. It opens up a means of adulteration. It is about as costly as a compound, if obtained in proper quality. Furthermore, it is extremely hygroscopic—the very quality we are trying to avoid. While it produces a dense concrete, it does not produce a water-repelling concrete, and absorption by capillarity is diminished, not destroyed. Walls treated with it will most likely require furring. Owing to its hygroscopic character, alternate absorption and loss of water may produce disintegration, as pointed out by Professor Baker in his book, "Masonry Construction."

Waterproofing surface coatings were used on buildings in ancient Rome and Greece. Some of the stone in the English Parliament buildings were saved from decay by surface treatment. One of the most notable examples in this country is the Obelisk in Central Park, which was treated with paraffin under heat. This was twenty years ago, and the material is still doing its work of keeping out water. Had

it not been treated, it would have been seriously injured by this time, as it could not stand the rigor of the northern climate.

Surface coatings have their greatest value in superstructural work. They have also been extensively used in reservoirs, bathing tanks, etc.

Probably the most permanent of the surface coating methods is the injection into the pores of the surface of hot paraffin, driving the material in quite deeply. The paraffin should be specially hardened to resist the sun's action. Being insoluble in acid or alkalis, and practically immune from atmospheric action, we obtain a very durable job, and the twenty years during which the Obelisk has been stubbornly resisting the attacks of the elements bear witness to its efficiency. This method is equally applicable to stone, brick, or concrete. It is an expensive process, but the result justifies the expenditure.

Another method of infusing the surface pores with paraffin is to prepare a supersaturated solution of the material specially hardened to resist sun action in a volatile carrier. This is applied with a stiff brush, the material being well rubbed into the pores. At least two, and preferably three, coats should be used. The carrier has great penetrating power, and upon its evaporation it leaves the paraffin in the pores. This method is much cheaper, but its life is much shorter. Work of this kind has remained perfectly tight over five years. This forms the basis of some of the commercially successful processes.

The Sylvester method of alum and soap is also a favorite method and one of the oldest. It requires, however, a larger number of coats, and it is just as expensive; it requires more labor and is not any more permanent than either of the others.

In this connection a word may be said on the subject of paints for concrete surfaces. The question is often asked whether an ordinary linseed oil paint will give a waterproof surface. There are two difficulties encountered in using an oil of this nature on concrete. First, linseed oil is an unstable compound—does not have a very long life. Again, the oil coming in contact with the alkali in the cement produces a soap which is soluble in water and is soon washed off.

A curious and interesting case of this kind occurred recently at Mt. Vernon, N. Y., when what was put forward as a special concrete paint was applied to the walls of an apartment house. Several months later the surface began to assume an ugly yellow color, and the painting contractor was called in to investigate. He began to rub off the paint, and the brush was promptly filled with soapsuds. He was at first inclined to believe that his brush or the water was not clean, and

fresh water and a new brush were brought to the work only to have the same experience repeated. The more he rubbed, the richer became the suds. It was not difficult to convince him that the combination of the alkali in the cement and the oil in the paint formed a soap. The entire surface had to be cleaned and a paraffine coating was applied.

Paints for concrete should be free from vegetable oils, and should be preceded by a waterproofing coat on exposed surfaces.

Before applying the dampproofing materials it is important—just as much so as in subsurface work—that the surface be dry and clean, and a competent inspector should oversee the conditions.

In buildings in course of construction the dampproofing may be accomplished by the application of a bituminous film over the inner surface of all exposed walls. A number of good materials especially prepared for this purpose are to be had, and ten years of experience have demonstrated their capacity for providing a perfectly tight wall when applied under right conditions. Not being exposed to the elements, they have a long life, and they obviate the necessity of furring and lathing, thus serving an economical purpose. They save the cost of an air space and prevent other disagreeable features which are indispensable accompaniments of the air space, such as the loss of space and the harbor afforded for vermin. They have, however, the disadvantage of not preventing efflorescence on the exterior. A large number of brick buildings have been treated in this way with satisfactory results. The film is a fairly good non-conductor, and it has some value as an insulating medium. Its use in concrete walls has been limited as before stated. Some large concrete buildings have, however, been recently treated by this method, and the action of the material is being watched with interest. Perhaps the most important building thus treated is the Monolith Building, on 34th St. and 6th Ave., New York.

One of the triumphs of modern waterproofing is to be found in the city of Pittsburg, for it is here that during the floods to which the city is periodically subjected, waterproofing is put to its severest tests. During these trying intervals, when millions of dollars are lost in the inundations which roll over certain sections of the city, a few of the more modern buildings bear eloquent testimony to the efficacy of the general design and waterproofing methods which had been employed, by their absolute immunity from damage by water, while adjoining buildings were severely injured.

This paper would hardly be complete without a word on the cost of

TABLE I.—VARIATION IN DIMENSIONS OF HOMOGENEOUS BODIES FOR CHANGE IN TEMPERATURE OF 100° F.

Material.	Change in Length per 100 Ft.	Increase in Area of 10′ × 10′ Surface.	Increase in Volume of 10′ × 10′ × 10′ Cube.
Brick	0.03′ = $\frac{3}{8}$″	0.06 sq. ft.	0.09 cu. ft.
Concrete	0.06′ = $\frac{3}{4}$″	0.16 "	0.40 "
Cement (neat)	0.06′ = $\frac{3}{4}$″	0.12 "	1.80 "
Granite	0.04′ = $\frac{1}{2}$″	0.08 "	1.20 "
Masonry (misc.)	$\frac{3}{8}$″ to 1.0′	0.06 to 0.16 "	0.90 to 2.40 "
Brick masonry	0.02′ = $\frac{1}{4}$″	0.04 "	0.60 "
Plaster	0.09′ = $\frac{1}{8}$″	0.10 "	2.70 "
Steel	0.06′ = $\frac{3}{4}$″	0.12 "	1.80 "
Iron	0.06′ = $\frac{3}{4}$″	0.12 "	1.80 "
Sandstone	0.04′ = $\frac{1}{2}$″	0.08 "	1.20 "
Pine wood	0.03′ = $\frac{3}{8}$″	0.06 "	0.90 "

MECHANICAL EFFECTS.

10 inch bar changing $\frac{1}{20}$ inch for 80° F. .... 50 tons.
1 lb. iron changing $\frac{1}{280}$ inch for 180° F. .... 16,000 ft. lbs. load.
Freezing water.............................. 10 tons per sq. in.
78″ concrete bar 1 : 3 : 6..................... Compressing 6500 lbs. per sq. in.
20,000 lbs.—30,000 lbs. per sq. in. recorded.

TABLE 2.—TESTS OF TREATED AND UNTREATED CEMENT.

	Ordinary Portland.	Portland with 2% Hydratite.	
Tensile		Tensile	
Neat 7 days	740	600	Decrease.
	832	640	
	854	655	
	900	674	
1 Cement 2 sand. 7 days.	400	460	Increase.
	438	464	
	452	473	
	464	500	
1 : 2. . 21 days.	495	602	Increase.
Adhesion between new and old concrete.			
1 : 2. . 7 days.	125	150	Increase.
	137	163	
	130	172	
	168	178	
Holding-power to brick.			
1 : 2. . 7 days.	550	395	Decrease.
	610	440	
	795	620	
	865	820	
Activity by Gillmor needle.			
Initial set. . 5 hrs. 40 min.		6 hours	
Final set. . . 8 hrs.		8 hrs. 45 min.	

the various methods of waterproofing. This, however, can only be touched upon here in a very general way. Table 4 shows the unit costs of various methods of waterproofing.

Table 5 shows the thickness of waterproofing required for various heads of water.

Much more could be said upon the subject, but what has been presented establishes the fact that waterproofing is an engineering question, and it is to be hoped that the engineering profession will treat it as such much more in the future than it has in the past.

TABLE 3.—TESTS SHOWING EFFECT OF WATERPROOFING COMPOUNDS ON CEMENT.

Portland Cement Mortar. 2% W. P. Compound.	Tension. Pounds per Square Inch.				Compression. Pounds per Square Inch.			
	7 Days.	28 Days.	90	6 Months.	7 Days.	28 Days.	90	6 Months.
Compound No. 1—Aquarex. Knickerbocker Chem. Co.	360	493		542	1580	2399		4493
Compound No. 2—Maumee. Maumee Chem. Co.......	340	475		575	1284	2299		4236
Compound No. 3—Medusa. Sandusky Portland Cem. Co....................	347	477		571	1295	2557		3272
Compound No. 4—Hydratite. A. C. Horn Co.....	342	476		591	1616	2549		3643
Portland Cement Mortar. No W. P. Compound.....	342	489		600	1632	2528		4841

Tests made by Spackman Engineering Co., Philadelphia.

TABLE 4.—COST OF WATERPROOFING.

Hot Coal-tar and Felt:

Horizontal { 1st Ply \$2.00 to \$4.00 per square (100 sq. ft.). Additional—\$1.50 to \$2.50 per square

Vertical.................................Add 10% to 25%
Pressure work..........................1 ply \$4.00 to \$5.00 per square.
Commercial Asphalt and Asphalt Felt.........Add 15% to 60% per ply.
Special Asphalts and Felts..................Add 30% to 50% per ply.
Cold process—felt or burlap.................same as commercial asphalt.
Asphalt Mastic 1″..........................15 cts. per sq. foot.
Cement waterproofing compounds
1″ on floors—½″ to ¾″ on walls.............8 to 30 cts. per sq. ft.
Dampproofing masonry walls
2 coats applied in place...................2 to 4 cts. per sq. ft.

TABLE 5.—THICKNESS OF WATERPROOFING REQUIRED FOR VARIOUS HEADS OF WATER.

HEAD IN FEET.	COAL-TAR AND FELT.	COMMERCIAL ASPHALT AND FELT.	SPECIAL FELTS AND COMPOUNDS.	ASPHALT MASTIC.	W. P. CEMENT MORTAR.
0.........	2 Ply	2 Ply	1 Ply	¼ in.	½ in.
1.........	3 "	3 "	2 "	½ "	⅝ "
2.........	4 "	4 "	3 "	½ "	⅝ "
6.........	5 "	5 "	4 "	½ "	⅝ "
8.........	6 "	6 "	5 "	½ "	¾ "
10.........	7 "	7 "	6 "	½ "	¾ "
15.........	8 "	8 "	7 "	¾ "	¾ "
20.........	9 "	9 "	8 "	¾ "	¾ "

DISCUSSION.

Mr. LEWIS.—It was my aim in the paper to treat the subject from a very much broader and more general standpoint than that considered in the discussion, which was chiefly devoted to the waterproofing of concrete.

Waterproofing concrete is only one phase of waterproofing engineering—an important one, to be sure, but not by any means the most important. Furthermore, the discussion on waterproofing concrete was limited particularly to the interconstruction period, when many things may be done to attain impermeability. There are numbers of concrete structures where waterproofing was not considered at the outset; and in such cases there is no possibility of making use of the membrane method, upon which method most of the discussion turned.

The remedying of damp and leaky conditions in buildings already constructed; the prevention of decay of delicate stone used in the construction of many of our finest buildings, and of the defacements resulting from efflorescence—all these are as much a part of waterproofing engineering as the procuring of impermeable concrete.

The criticism that the paper did not give specific recommendations for treatment in various conditions is, I admit, well directed. Although I may justly claim that the methods to be adopted in cases most ordinarily met with were touched upon in my paper, I wish to explain that it was in anticipation of this very criticism that I purposely omitted a greater elaboration of these methods, believing that the discussion, which it was expected would follow the paper, would prove a more effective way of bringing these methods before the Association. I very much regretted that the lateness of the hour prohibited any such discussion.

A great deal of criticism was launched against waterproofing compounds, some of the speakers going so far as to condemn most of them as of little value. These statements are usually too sweeping and are prone to be unjust, unless the particular instances in which the compound failed to give results are stated.

No one familiar with waterproofing problems will expect that a material exposed to the elements will last forever. The individual who discovers such a material will establish his title as a benefactor to the human race, and none will

dispute his claim to all the distinction and pecuniary reward incident to such a discovery.

There are about twenty properties which a waterproofing material must possess to make it ideal, and some of these are so antagonistic as to make the attainment of absolute perfection impossible.

In the case of waterproofing materials where they have been properly installed it must be reasonably expected that occasional renewals will be required, as in other parts of the structure. If, for instance, we can keep our buildings free from dampness at no greater expenditure than a few cents per square yard per year, and renewal is required not oftener than once in five years, we should not grumble.

If by the application of the best means available we make our substructures immune to water penetration, our reservoirs immune to leakage, and our superstructures free from the injurious action of water for a length of fifteen, twenty, or thirty years, as it is admittedly possible to do, should we hesitate to make use of this protection because we are not sure that the material will wear for more than thirty years?

Iron and steel will rust; timber will rot; delicate stones will decay; but we do not, for these reasons, discard the use of these materials, nor pronounce them useless because they are not altogether indestructible.

In making a selection of waterproofing, we must look for that which gives the best hope for a reasonably long life, commensurate with their cost, taking care that location as to accessibility in the event of repairs be given due consideration.

Taking up the discussion, I wish first to notice some of the statements made by Mr. Humphrey:

First, that fifty compounds are on the market as a result of concrete block manufacturing.

It is a fact that the concrete block industry has given an impetus to waterproofing development; but most of the compounds have been on the market for many years, for purposes other than purely concrete work; and there are thousands of structures all over the country in which numbers of these compounds have been used with satisfactory results. The statement that they are "temporary expedients of doubtful value" may be indicated by laboratory tests, but in actual practice there is abundant evidence to disprove this wholesale assertion. The constantly increasing consumption of various kinds of waterproofing materials is the most convincing of all proofs that consumers find in them a good investment.

The statement that the percolation of impure water causes concrete to become tight is true; this is almost a self-evident fact; and in 1903 the matter was clearly brought out in a topical discussion in the American Society of Civil Engineers, and it is well known to any one familiar with waterworks. This is applicable principally to reservoirs or standpipes. We certainly cannot wait for the elements to clog up the pores in a concrete block building,—a process which, as Haglock states, will take from three to twelve years,—suffering, meanwhile, all the inconvenience, annoyances, sometimes irreparable injury, incident to water-soaked walls.

The statement that it is doubtful whether more than one method is available under all conditions is entirely unwarranted; and this is a point which I have endeavored to make clear. If Mr. Humphrey refers to the particular case of mass

concrete, he may be right; but if he refers to one method for waterproofing in general, it is, as I have said, entirely unwarranted.

Surely, Mr. Humphrey would not employ the same method for dampproofing an exposed brick wall as that for combating a heavy water-pressure in a substructure. Neither would he take the same means for treating sewage-contaminated walls as for excluding dampness from a block house. I take it that his statement covered in its meaning only the one case of mass concrete treated during construction.

Mr. Humphrey states that paraffin is useless as a means of waterproofing concrete if it cracks. There is only one condition underw hich the writer recommended the use of paraffin, and that is to provide against dampness in a concrete structure already erected. Applied hot or cold, it is purely a surface application, which penetrates about one-quarter of an inch, and destroys the capillarity of the concrete. The only practical way in which superstructural walls, after having been erected, can be made water-tight, if found leaky, is by an exterior application; and of the various materials, paraffin is the most durable and effective. It is not merely in the case of concrete that paraffin exerts a preserving influence: it is equally effective when applied to brick, limestone, sandstone, etc., and countless structures whose walls were composed of costly and delicate building stone have been preserved from incipient decay by timely applications of this material. Every one knows that the symptoms of disintegration which began to disclose themselves some twenty years ago in what is justly regarded as one of the treasures of Central Park—the Obelisk—were effectively arrested by applications of paraffin, and the wisdom of this treatment has been abundantly proved in the two intervening decads, the Obelisk maintaining still the soundness of surface which for a time seemed to be threatened by its contact with a new and trying atmosphere.

All surface applications require periodic renewal—paraffin solutions, once in four or five years; when applied hot, perhaps once in ten or fifteen years, and the expense is fully warranted by the results obtained when used.

The statement that one of the specimens which Mr. Humphrey tried generated maggots is very interesting. In my opinion, the sample in question simply had casein as one of its constituents, and this being a vegetable product, may help explain the phenomenon. It indicates the necessity for inspection and testing referred to in the paper. The paper mentions maggots developed in a large office subbasement, due probably to sewage contamination which attacked the asphalt waterproofing.

Paraffin coatings are also serviceable in standpipes and small tanks when rigidly constructed; but where any settlement is liable to occur, or where the structure is not properly reinforced, or is unstable in position, neither paraffin nor any other surface coating can be employed with satisfactory results.

As to the materials which are added to cement dry to make the cement impervious, which Mr. Humphrey so recklessly condemns, their durability may be uncertain, as stated in the paper, although some work is on record five years old which is still in first-class condition.

Unquestionably some of the advertised materials are of no value—gotten up for catch-penny purposes; but it is a mistake—the reverse of a progressive broad-mindedness—to condemn all because a few have proved worthless. Aside

from their value as waterproofing agents or their durability, the addition of a very finely powdered material is efficacious as a void-filler, increasing the sand-carrying capacity of a cement.

Furthermore, in using the waterproofed cement—to which hydratite, medusa, etc.,has been added—as a mortar coat the labor in troweling is greatly reduced—so much that the cost of the materials is made up by this saving. No better evidence of this can be given than that all the cement waterproofing work done in the largest buildings in New York has had a water-repelling compound incorporated in the cement, largely for the purpose of reducing the troweling cost. The explanation is that the very hard finish is not so necessary when a repellant compound is employed as when it is not incorporated. The materials most serviceable for this work are those having a metallic stearate as their principal ingredient.

Mr. Humphrey alludes to the temperature changes in the interior mass of concrete as not being very great. Concrete has a low rate of conductivity, but exposure during the seasons to the elements produces very appreciable changes in dimensions, as is shown by large cracks, as much as one inch in size, opening in large in winter and entirely closed in summer. The recent "Transactions" of the American Society of Civil Engineers contains some valuable data on temperature changes in masonry masses.

Mr. Humphrey also asks: "Are elastic coatings really elastic?" Any one can readily convince himself of the elasticity of a good grade of felt and asphalt by a simple trial. A good material should show no cracks when bent or doubled up on itself.

Mr. De Knight complains that the paper gives no conclusion. As stated at the outset, it does not give direct conclusions, and to supply the deficiency, to which Mr. Quimby also refers, I have prepared a series of specifications of some representative work. I regret that Mr. De Knight did not take up the question of waterproofing engineering from its broad point of view. His discussion is limited exclusively to the one phase of the subject—concrete during construction; and while interesting, and apparently logical, it is by no means conclusive. The statement that everything has a prototype in nature is purely problematical; therefore, his arguments have no definite premise. I agree that it is better not to allow the water to reach the concrete, and the membrane method I believe to be advisable where the work is unstable, subject to uncertain settlement and where space is not too valuable. I believe in the membrane method for reservoirs and unreinforced structures generally. But in modern office buildings, where space is of great value, and where foundations are built with greatest care, the settlement is slight. In such cases a saving in space,—which is very considerable,—the advantage of having the waterproofing where repairs can be readily effected, and the saving of the expense involved in constructing supporting walls, etc.—all these considerations lead me to favor the integral rigid method, notwithstanding the disadvantage of the water reaching the concrete.

I certainly would hesitate to make this statement if I did not have evidence of the successful results achieved in some of the most difficult problems that have recently come up in the field of waterproofing, as shown in many of the representative structures erected in New York and elsewhere during the past few years.

A new method is always regarded in somewhat the light of an innovation,

and hence is open to criticism and doubt by those who pin their faith to old-time theories and practices. There are, in this instance, however, insurmountable facts, in the form of successful execution, as shown in a long list of million-dollar buildings, which are sufficient to refute the arguments of Mr. De Knight and overcome the skepticism of Mr. Humphrey and Mr. Quimby as to the value of some of the compounds which represent the integral method.

The execution of this work demands the most painstaking care; and it is always advisable to have it in charge of a skilled contractor and under a guarantee. Where this is found inexpedient, especially expert plasterers should be employed. I append a detailed description of the method of applying these coatings.

Where the work cannot be given the attention it requires, the membrane method would be safer to employ.

How would Mr. De Knight employ the membrane method in, for instance, a cellar which is reeking with water? Would he excavate all around and underneath the cellar? Would he build a false wall on the interior? How would he prevent dampness in a concrete, brick, or stone superstructure? Surely, not by an exterior membrane of bituminous material. Would it not be to the advantage of the membrane method to admit that there are some limitations to its use?

Mr. De Knight also makes some statements which, while not a part of the subject, are open to criticism. Is engineering an exact science, as he says? Not so. It is anything but exact. The only exact things about engineering are pure mathematics and astronomy. Almost all engineering calculations are based on more or less uncertain theories and assumptions and experimental data. There is hardly one frequently used engineering formula where the exactness is not questionable. No part of engineering is perhaps more inexact than the very one we are now considering—the laws of the flow, absorption, and penetration of water through earth and solid bodies: The efforts of engineers from time immemorial have been to make the science exact, but, while a great deal of light has been thrown on the subject and a great deal of knowledge obtained thereon, exactness is still a long way off.

Referring to Mr. Shrover's statement that in the integral systems he has seen the structure was underdrained—this is very true. In all cases where appreciable pressure is encountered there should be an emergency drainage system at hand if required; this applies to the membrane method as well. Water should be led, not fought, as De Knight puts it. Where pressure is great, it is cheaper to drain into sewers than build walls heavy enough to stand the pressure. Why should the expense be augmented by heavy construction when by the simple expedient of drainage the pressure could be relieved, and the walls made immune to danger from pressure cracks? Drainage reduces the problem of waterproofing to that of dampproofing and simplifies the construction materially.

Mr. Shrover asks about reservoir waterproofing. The best method to adopt in waterproofing a reservoir is to construct a concrete or brick underbed, place thereon a continuous bituminous lining attached at frequent intervals to the masonry lining underneath, but not too rigidly, lest there be danger from settlement. This should be protected by a covering of concrete laid in sections having expansion joints filled with asphalt. The settlement of reservoir embankments is usually too great, especially during the first few years, to allow either a super-

ficial coating of any kind or specially treated concrete to be of any great value. Rigidity may be obtained by proper reinforcement, but the expense incidental thereto would make such a provision prohibitive.

Mr. Quimby states that Portland cement mortar may be troweled on and be water-tight without the addition of any compound. I agree with him; but, as I said before, experience has shown that the labor reduction in troweling by the use of compounds is sufficient to warrant the incorporation of such compounds, and, besides this, a better job results. He also inquires whether asphalt is durable and whether coal-tar is not, and vice versâ. Both are durable in ordinary earths and protected from the elements; where the ground is saturated with sewage, grease, or oils, asphalt is liable to be attacked, while coal-tar has greater resistance. Asphalt is more elastic than coal-tar, and maintains its elasticity through a much wider range of temperature. Coal-tar becomes brittle when cold, while asphalt does not, and the former melts more rapidly. Therefore, for work protected from freezing and heat coal-tar is to be preferred because of its cheapness. Otherwise, asphalt should be employed. When the work is free from water-pressure, and only dampness below ground is to be combated, asphalt dissolved in one of its solvents applied cold may be employed, doing away with the heating outfit. This, however, cannot be made to stick well to a wet wall, as dampness would nullify any attempt at adhesion.

The arch, subject to flowing water, should preferably be treated with the membrane method, using either coal-tar or asphalt with a proper fabric. The settlement of the arch filling precludes the use of the integral method, unless the structure is specially designed for the work.

The writer never suggested the use of either paraffin or other purely surface coatings for underground work. They have no value in such locations, being subject to abrasions by contact with filling, and affording no bond for a protective coat of mortar, as may be had with bituminous materials. These coverings, as already stated, are for dampproofing buildings after erection, or for such work as tanks or wells, subject to little or no settlement. Under these conditions they will last from three to perhaps fifteen years, dependent upon the surfaces, material, and workmanship. Thousands of structures have been treated with them.

There is only one other question occurring in the discussion which I believe I have not touched upon; that is, how to waterproof pipe passages and tighten openings through walls for various purposes.

In using the membranous method, where felt and asphalt or pitch compounds are employed, a very effective way of making a water-tight connection between pipes and the waterproofing is to use a heavy sheet-lead flashing, to be made absolutely water-tight where it connects with the pipe. This flashing should go out over the waterproofing, and after being put in place should be coated over with the compound, and a water-tight connection made with the waterproofing by using the strips of felt and the compound.

In cases where the integral method of waterproofing concrete walls or floors is employed, the openings around pipes or outlets can be made water-tight by removing all dirt, grease, or foreign substance from such pipes or outlets, so that the cement mortar with the waterproof compound added can get absolutely perfect adhesion to the metal. In cases where pipes penetrating walls are liable

to be subjected to expansion and contraction it is necessary to have the tube in direct touch with the concrete of a large enough diameter for the main pipe to pass through it, leaving a free space, and on the water-pressure side a water-tight connection should be made in the wall by means of a gas-jet.

EXTRACTS FROM SPECIFICATIONS FOR WATER-PROOFING.

Recent Specifications for Waterproofing New York Rapid Transit Subway.

1. It is the very essence of these specifications to secure a railroad structure underground which shall be free from the percolation of ground or outside water.

2. To this end, the placing and protection of the waterproofing shall be as herein provided and as shown on the plans.

3. The protecting masonry shall be hollow terra-cotta blocks, common bricks, or concrete, laid as herein elsewhere provided, and shall not be less than 4 in. in thickness.

4. In places where permanent sheeting is placed at the waterproofing line, the waterproofing, if permitted by the engineer, may be applied against the sheeting.

5. All surfaces to which waterproofing is to be applied shall be made as smooth as possible; on these surfaces there shall be spread either hot melted pitch or asphaltum in a thick layer of uniform thickness; on this layer of pitch or asphaltum shall be laid a fabric of such material as may be approved by the engineer: this process shall be repeated until such number of layers as may be required by the engineer have been placed, and a final coat of pitch or asphaltum shallt hen be applied.

6. The term "ply," as used in these specifications, shall mean a layer of treated fabric, both sides of which shall be coated with pitch or asphaltum at the time of laying.

7. The number of plys on the sides and under the floor shall in no case be less than three in ground that is quite dry; where there is a water pressure against the masonry equal to ten feet, not less than six plys. Where the water pressure is less than ten feet, such number of plys, between three and six, shall be used as the engineer may direct. The number of plys on the roof shall not be less than four.

8. In all cases over the station roofs, and also against other portions of the structure where the head of ground water is ten feet or more, two plys of waterproofing, as described above, shall be used, together with one or more layers of brick laid in asphalt mastic; the number of layers of bricks, not exceeding three, shall be determined by the engineer. Said bricks, before being laid, shall be thoroly dried and warmed. At all other points where the pressure of ground water is less than ten feet, the contractor may substitute in lieu of the number of plys, as described above, one ply in hot asphalt, and one or more courses of brick laid in asphalt mastic, as the engineer shall direct.

SPECIFICATIONS FOR MATERIAL.

9. Asphalt mastic shall contain one-third pure bitumen, the other ingredients to be sand and lime dust or cement, in proportions governed by local requirements and weather conditions.

10. In those portions of the structure where the ground is dry, the regular waterproofing, excepting on the roof and for a distance of not less than four feet on the sides, may, if approved by the engineer, be omitted; in arched cut and cover work, waterproofing as called for above may be omitted, at the option of the engineer, but the extrados of the arch shall be coated with hot pitch or asphaltum of the quality described.

11. Any masonry that is found to leak at any time prior to the completion of the work and final acceptance thereof by the Board shall be cut out and the leak stopt.

12. Pitch shall consist of either coal-tar or natural asphalt, as the engineer shall select.

13. The coal-tar pitch shall be straight-run pitch which will soften at 70° F. and melt at 100° F., being a grade in which distillate oils, distilled therefrom, shall have a specific gravity of 1.105.

14. The asphalt used shall be the best grade of Bermudez, Alcatraz, or lake asphalt of equal quality, and shall comply with the following requirements:

15. The asphalt shall be a natural asphalt or a mixture of natural asphalts, containing in its refined state not less than ninety-five per cent. of natural bitumen soluble in rectified carbon bisulfide or in chloroform. The remaining ingredients shall be such as not to exert an injurious effect on the work. Not less than two-thirds of the total bitumen shall be soluble in petroleum naphtha of seventy degrees Baumé or in acetone. The asphalt shall not lose more than four per cent. of its weight when maintained for ten hours at a temperature of 300° F.

16. The fabric to be used, with the pitch or asphaltum for waterproofing, shall have been treated with pitch or asphaltum or another suitable material before being brought on the work. The fabric and the material used in its treatment shall be approved by the engineer.

17. All concrete shall be dry before waterproofing is attacht. If for any reason it is impracticable to have the concrete dry, then there shall be first laid a layer of the treated fabric, on the upper surface of which is to be spread the first layer of pitch or asphaltum; the said layer of fabric shall not be counted as of one of the required plys.

18. Each layer of pitch or asphaltum fluxt as directed by the engineer must completely and entirely cover the surface on which it is spread, without cracks or blowholes.

19. The fabric must be rolled out into the pitch or asphaltum while the latter is still hot, and prest against it so as to insure its being completely stuck over its entire surface, great care being taken that all joints are well broken, and that the ends of the rolls of the bottom layers are carried up on the inside of the layers on the sides, and those of the roof down on the outside of the layers on the sides, so as to secure a full lap of at least one foot. Especial care must be taken with this detail.

20. None but competent men, especially skilled in work of this kind, shall be employed to lay the waterproofing.

21. When the finisht layer of concrete is laid over or next to the waterproofing material, care must be taken not to break, tear, or injure in any way the outer surface of the pitch or asphaltum.

SPECIFICATIONS FOR OBTAINING DAMP- AND WATER-PROOF STRUCTURES.

By the Use of Special Compounds—Bituminous Method.

1. *Intent:* It is the intent of these specifications to secure a substructure that will be entirely free from dampness and water penetration, and to that end the contractor shall supply the material and perform the work in accordance with the plans and the following specifications:

1a. *Surfaces to be Waterproofed:* To waterproof the entire substructure of a bilding, the damp-course must be carried over all footings, piers, and walls, over the entire cellar bottom, and on the outer face of all the foundation walls.

2. *Condition of Surface:* All walls to be waterproofed must be in a condition fit to receive the same, namely: dry, and if concrete walls, must have been allowed to set thoroly. Rough walls must be smoothed with a coat of cement mortar.

3. *Connecting Vertical with Horizontal Waterproofing:* To insure the continuity of the damp-course, the same must be allowed to lap at least 6 in. on both sides, over all footings, piers, and walls, so that the horizontal and vertical waterproofing may be properly connected.

4. *Back-filling:* After the waterproofing of the outer foundation walls has been done, it should be immediately back-filled to protect the coating from abrasion.

5. *Retaining Wall:* If to waterproof the outer face of foundation wall necessitates additional excavation, a 4-in. retaining wall of brick (which is to be independent of the house wall) may be bilt to receive the damp-course; should this method be employed, the house wall must be immediately bilt against the waterproofing and the back of the wall against the damp-course, well slusht in.

6. *Pits and Trenches:* Where there are pits, trenches, engine and boiler beds, they should be waterprooft, connecting the damp-course to that on the cellar floor.

7. *Water Pressure:* Wherever water-pressure is found, a sufficient resistance to this pressure must be provided in order to preserve the integrity of the damp-course.

8. *Resistance for Vertical Damp-course:* To accomplish this, it is necessary to carry the waterproofing of outside walls, within the walls, or on the outer face of the walls, to 6 in. above grade, in this manner obtaining the solid backing of the masonry to counter-balance the pressure that may be developt.

9. *Horizontal Damp-course:* The waterproofing should be applied to the underbed of concrete on cellar bottoms, which must be previously floated to a smooth surface to receive the damp-course; the top of the waterproofing sheet must receive a safety coat of at least 2 in. of cement mortar before the main body of concrete is laid down.

10. *Safety Coat:* This safety coat to be made of one part cement and two and one-half parts good sharp sand; the object of this coat is to protect the damp-course from being punctured by the ramming of the rough or top bed of concrete.

11. *Resistance for Horizontal Damp-courses:* Where there is considerable water pressure, the top bed of concrete should not be less than 18 in. thick;

should the substructure be much below the low-water mark, sufficient concrete must be added (in weight) to resist the hydrostatic pressure.

12. *Drainage:* Water pressure is best relieved by the use of automatic siphons and sump-pit, together with tile drains, and wherever this is done, a decrease in resistance on top of the damp-course can be made.

13. *Materials Employed in Damp-Course:* All waterproofing must be done in most approved manner, using (here specify materials desired) as (manufactured).

Apply to all surfaces to be waterproofed one heavy coat of (the material specified), care being taken that the surface to which it is applied is dry, and that the coating has been applied thoroly, and that no pinholes or other spaces are left uncovered.

Directly after this coat has been applied, lay the fabric to the surface of it, pressing the same down firmly, in order that the entire sheet may adhere to the wall; care must be exercised that the fabric is properly lapt, and that between the laps, sufficient of the waterproofing material is applied to cement them thoroly to each other. Over the fabric apply one or more heavy coats of the material chosen, as conditions may require.

Properly connect the damp-course over the footings with that on the outer face of the wall and also with the damp-course over the cellar floor.

If the substructure is below low-water mark, increase the damp-course by adding such number of layers of fabric and additional coats of waterproofing material as the architect may direct.

By the Use of Cement Waterproofing Compound—Integral Method.

1. *Intent:* It is the intent of these specifications to obtain a pumping-chamber free from the penetration of ground water, so that the machinery employed therein will not be subject to corrosion due to the presence of water or moisture.

2. *Method of Procedure:* Watertightness shall be secured by proportioning the ingredients of the concrete composing the walls and floor of the chamber so that the voids in the same shall be reduced to the minimum as far as practicable, in accordance with the foregoing specifications and by the addition to the cement of a dry powdered paraffinated waterproofing compound. In addition, the inner surface of the chamber walls and floor shall be surfaced with an unbroken continuous coat of cement mortar, to which such waterproofing compound has been added. The   compound, as manufactured by   , or its equal may be used for waterproofing the cement or imparting to the latter its water-repelling properties.

3. *Proportions:* The proportion of the waterproofing compound in the body of the concrete work shall be not less than 4 lbs. of compound to each barrel of cement employed for making this concrete.

4. *Surface Coat:* The surface coat shall be not less than 1 in. in thickness on the floors and $\frac{5}{8}$ in. on walls, and shall consis of 1 part Portland cement and $2\frac{1}{2}$ parts sand and 8 lbs. of waterproofing compound to each barrel of cement employed in making such surfacing.

5. *Mixing:* The waterproofing compound must be added dry to the cement, and the two thoroly mixt until a uniform mixture is obtained. Under no circumstances must the compound be added after the cement has partially set or has been mixt with sand. The sand shall be slightly moistened before mixing with the cement.

6. *Laying:* Great care shall be taken in placing the concrete so that maximum density will be secured. A wet mixture shall be used, the proportion being at least 1 part cement to 5 parts sand and stone or gravel.

7. *Uniting Old and New Concrete Surfaces:* Before laying new concrete upon old work, the surfaces of concrete already set shall be thoroly washt with material prepared for such purposes. This washing shall be followed by washing with water. Upon the surface thus prepared the new concrete shall be laid. The manufactured by , or its equal may be employed for this purpose.

8. *Laying the Surface Coat:* Great care shall be exercised in laying the surface coat of waterprooft cement mortar on the walls or floors. The concrete surfaces to which same is to be applied shall be clean and roughened or scratched if the engineer shall so direct, to secure a good bond with the surface coat. If ordered, the surfaces shall be washt as above described before the finishing coat is placed.

9. *Finishing Coat:* When the concrete, after being treated as above described, presents a thoroly satisfactory appearance, the finish coat shall be applied or "floated" to the floor and walls by men especially skilled in this class of work, and a perfectly smooth, true, and uniform plaster surface shall be obtained, free from cracks, blow holes, pin holes, or other defects.

10. *Water Pressure:* Water pressure against the walls or floor of the chamber shall be relieved by draining and pumping if necessary until the surface coat is sufficiently hard and bonded to the concrete walls and floor so that it can resist said pressure by its own adhesive power.

11. *Approval of Engineer:* The surfaces of the concrete of the walls and floor shall be in a condition satisfactory to the engineer when the finishing coat is being applied and said finishing coat is to be kept moist by spraying or otherwise, and protected from frost and sun while it is in the process of setting.

12. *Setting Time:* No walking or rolling of wheel-barrows will be permitted on the finisht floor of the chamber until the surface finish shall have been allowed to set for at least seven days, or longer if the engineer shall so direct.

SPECIFICATIONS FOR WATERPROOFING A PUMPING CHAMBER IN GROUND UNDER EXTERNAL HEAD OF WATER.

Bituminous Method, using Coal-tar and Felt.

1. *Intent:* It is the intent of these specifications to obtain a pumping-chamber free from the penetration of ground water, so that the machinery therein will not be subject to corrosion due to the presence of water or moisture.

2. *Proviso:* The placing and protection of the waterproofing shall be done in accordance with the plans and specifications herein provided.

3. *General Description:* Waterproofing shall consist of an unbroken continuous bituminous shield, completely enveloping the walls and floor of the chamber. The vertical portion is to be erected against a brick or concrete wall at least 4 in. in thickness, which has previously been bilt against the sheet piling employed for making and protecting the excavation. This shield shall be protected from injury during the laying of the concrete walls of the chamber by a protecting

coat of cement mortar. The horizontal portion of the shield is to be constructed on an under layer of concrete at least 6 in. thick.

4. *Materials:* The bituminous shield shall be made up of no less than four alternate layers of the best grade of tarred felt, cemented together with the best grade of coal-tar pitch. The coal-tar pitch shall be straight run, which will soften at 70° F. and melt at 100° F. The felt shall be a first-class quality, thoroly saturated with coal-tar or other material acceptable to the engineer.

5. *Condition of Surfaces:* All surfaces to be waterprooft shall be as smooth as possible and shall be dry.

6. *Laying:* On the prepared surface shall be laid a uniform layer of that melted pitch. Then first layer of the fabric shall be rolled out into the pitch while the latter is still hot, and prest against it so as to insure its being completely stuck over, and shall be free from all blow holes, pin holes, or other imperfections.

7. *Carrying Waterproofing Against Sheet Piling:* In case tung and grooved sheet piling is used for making and protecting the excavation and this piling has been treated with an efficient wood preservative satisfactory to the engineer, the 4-in. brick retaining wall previously described may be dispensed with, and the wall waterproofing carried up against the sheet piling. The sheet piling shall be given a thoro coat of hot pitch and all joints thoroly filled before the first layer of felt is placed thereon. Coppered carbolineum or other wood preservative satisfactory to the engineer may be used for protecting the sheet piling.

8. *Connections:* Great care shall be taken in connecting the fabric at the junction of the floor and walls, a lap of at least 12 in. to be allowed for same. The ends of the rolls of the floor fabric shall be brought up on the inside of the layer on the walls. Where it is necessary to stop work, a lap of at least 12 in. shall be provided for connecting on the adjacent portion of the work. Upon this layer of fabric shall be spread a second layer of hot pitch as before, and these operations continued until the requisite number have been placed, the last layer of felt being covered with a final coat of hot pitch.

9. *Protection:* The bituminous shield herein described shall be protected from injury by a coat of cement mortar mixt in the proportion of 1 part Portland cement to 2 parts sand, which shall be placed upon the waterproofing within twelve hours of the placing of the latter, or sooner if the engineer shall so direct. Should the waterproofing be injured, owing to failure of placing the protective coat of cement mortar, which injury is caused by exposure to weather, bulging from masonry surface of puncturing from any cause, the contractor shall remedy the same at his own expense.

10. *Placing the Concrete:* Concrete of the walls and floor shall be placed carefully upon the protecting mortar surface, care being taken not to injure the latter.

11. *Water Pressure:* The work shall be free from water pressure during the laying of the waterproofing, being relieved by draining, and pumping if necessary.

12. *Skilled Labor:* Necessary working room must be provided for the proper execution of the work, and none but men skilled in this work shall be employed.

13. *Caution:* No waterproofing shall be done when the temperature is below 25° F.

SPECIFICATIONS FOR WATERPROOFING PENNSYLVANIA-LONG ISLAND RAILROAD TUNNEL.

The following are the specifications followed in providing for the waterproofing of the Pennsylvania-Long Island tunnel:

1. In tunnels driven with shields, the cast iron shells will serve as waterproofing.

In tunnels driven in the ordinary manner without shields, the space between the side of the excavation and the neat line shall be filled with concrete behind suitable forms. After the forms are removed the surface of the concrete shall be given a half-inch coat of mortar containing equal parts, by volume, of Portland cement and sand troweled smooth. After the mortar has set and dried out, it shall be covered with alternate layers of coal-tar pitch and felt—seven layers of pitch and six of felt. The felt shall be "Hydrex" felt, manufactured by F. W. Bird & Son, of East Walpole, Mass., or felt equally satisfactory to the engineer. The pitch shall be straight run coal-tar pitch, which will soften at 60° F. and melt at 100° F., being a grade in which distillate oils, distilled therefrom, shall have a specific gravity of 1105. It shall be mopt on the surface of the concrete to a uniform thickness of not less than $\frac{1}{16}$ inch. Immediately on this coat of pitch, and while it is still melted, there shall be laid a covering of felt, the sheets to lap not less than 4 in. on cross joints nor less than 12 in. on longitudinal joints, and to be made to adhere firmly to the pitch-covered surface of the concrete everywhere. This felt layer shall be mopt with pitch as above described, another layer of felt then added and mopt with pitch, and the process continued to the full number of layers required. This waterproofing shall extend from the level of the bottom of the electric ducts to 15 degrees above the spring line of the roof arch. After the waterproofing has been placed the remainder of the concrete, with the electric ducts, etc., shall be placed.

2. Where roofs of tunnels driven in the ordinary manner without shield are of brick, they shall be plastered with a mastic containing coal-tar and Portland cement in such proportions as the engineer may from time to time require. This shall be applied with a trowel in a uniform layer half an inch thick, containing equal parts by volume of Portland cement and sand, and the joints completely filled with mortar of the same composition. The junction between the waterproofing in the roof and sides shall be formed so as to make a continuous waterproofing surface.

3. Where the roofs of tunnels are of concrete bilt solidly against the rock, the waterproofing of the roof shall consist of grout injected thru pipes bilt into the concrete at such intervals as the engineer may require.

Where tunnels are bilt by the cut and cover method, the sides, if in rock excavation, shall be waterprooft as described in paragraph 1; if in earth excavation, they shall be waterprooft as herein specified for roofs. The roofs of tunnels will be plastered smooth and covered with coal-tar and felt, as specified for sides of tunnels in paragraph 1. The waterproofing shall be covered with a one-inch layer of mortar, containing equal parts, by volume, of Portland cement and sand. The mortar will be laid on in areas about 5 feet square, and when one square is set the adjacent ones will be laid tight to it, this laying out in squares being for

the purpose of relieving expansion or contraction. A thoro connection shall be made between the waterproofing of the top and sides.

5. The waterproofing of retaining walls and portals shall extend from the base of the wall to within one foot of the top. Where the walls are bilt against the face of rock excavation, the waterproofing shall conform to the requirements for sides of tunnels in paragraph 1; where the wall is not bilt against a rock face, the waterproofing shall be the same as specified for tunnel roofs in paragraph 2.

6. Where the floors of tunnels or approaches are on rock, no waterproofing will be used in the floors except when specially required by the engineer, and will then be paid for at the rates named in the schedules of unit prices. Where the floor is in earth, a layer of concrete 6 inches thick shall first be laid and covered with a half-inch coat of mortar containing equal parts, by volume, of Portland cement and sand, and troweled smooth, on which the waterproofing of pitch and felt specified in paragraph 1 shall be laid and the remainder of the concrete for the invert then added.

7. Waterproofing and the protecting mortar coat must be protected from injury by working or walking thereon, or during the filling of rock packing over tunnel roofs, or while placing back-filling behind retaining walls.

SPECIFICATIONS FOR WATERPROOFING CONCRETE BRIDGES—CHICAGO & NORTHWESTERN RAILWAY.

1. *Material:* (a) Asphalt shall be used which is of the best grade, free from coal-tar or any of its products, and which will not volatilize more than ½ of 1 per cent. under a temperature of 300° for ten hours.

(b) It must not be affected by a 20 per cent. solution of ammonia, a 25 per cent. solution of sulfuric acid, a 35 per cent. solution of muriatic acid, nor by a saturated solution of sodium chloride. It should show no hydrolytic decomposition when subjected, for a period of ten hours, to hourly immersions in water with alternate rapid drying by warm air currents.

2. *Range of Temperature:* (a) For metallic structures, exposed to the direct rays of the sun, the asphalt must not flow under 212° F., nor become brittle at 0° F. when spread thin on glass.

(b) For structures under ground, such as masonry arches, abutments, retaining walls, foundation walls of buildings, subways, etc., a flow point of 185° F., and a brittle point of 0° F., will be required.

(c) A mastic made from either grade of asphalt by mixing it with sand must not perceptibly indent when at a temperature of 130° F. under a load of 20 pounds per square inch. It must also remain pliable at a temperature of 0° F

3. *Preparing Surface:* (a) Before applying asphalt to a metal surface, it is imperative that the metal be cleaned of all rust, loose scale, and dirt, and if previously coated with oil this must be burnt off, with benzine, or by other suitable means. The metal surface must be warm to enable the asphalt to adhere to it, and the warming is best accomplisht by covering it with heated sand, which should be swept back as the hot asphalt is applied.

(b) When waterproofing masonry structures, if the surface cannot be made dry and warm, it should first be coated with an asphalt paint applied cold. This is particularly necessary for vertical surfaces. It is difficult to make either cold

or hot asphalt adhere to the surface of concrete or mortar when the latter is covered with a thin film of cement. To overcome this the surface of the structure should be covered with a finishing coat of mortar composed of one part of cement to one part of sand. If this is not permissible, the surface should be cleaned with a sand blast.

4. *Preparing Asphalt:* The asphalt should be heated in a suitable kettle to a temperature not exceeding 450° F. If this is exceeded, it may result in "pitching" the asphalt. Before the "pitching" point is reached, the vapor from the kettle is of a bluish tinge, which changes to a yellowish tinge after the danger point is passed. If this occurs, the material should be tempered by the addition of fresh asphalt. The asphalt has been cookt sufficiently when a piece of wood can be put in and withdrawn, the asphalt clinging to it. Care should always be taken not to prolong the heat to such an extent as to pitch the asphalt; should it become necessary to hold the kettle for any length of time, bank or draw the fire and introduce into the kettle a quantity of fresh asphalt to reduce the temperature.

5. *Application of Asphalt:* (a) The first coat should consist of a thin layer poured from buckets on the prepared surface and thoroly mopt over.

(b) The second coat should consist of a mixture of clean sand or limestone screenings, free from earthy admixtures, previously heated and dried, and asphalt, the proportion of 1 part asphalt to 3 or 4 parts sand or screenings by volume; this is to be thoroly mixt in the kettle and then spread out on the surface with warm smoothing irons, such as are used in laying asphalt streets. The irons should not be hot enough to burn the asphalt.

(c) The finishing coat should consist of pure hot asphalt spread thinly and evenly over the entire surface, and then sprinkled with washt roofing gravel, torpedo sand, or stone screenings, to harden the top.

(d) The entire coating should not be less than 1 in. thick in the thinnest place.

DIRECTIONS FOR APPLYING WATERPROOF CEMENT COATINGS.*

Waterproof Coatings.—The waterproof coating referred to below is to be prepared by the mixing of 1 part of first-class Portland cement to 2 parts sand, well graded from coarse to fine. Two per cent. of a first-class water-repellant compound in a finely divided state is to be thoroly mixt dry with the cement before the sand, previously moistened, is mixt with same.

Note.—No other than clean, clear water shall be employed by the waterproofer, either for cleansing of the surfaces to be coated or for mixing the coating ready for use. Not less, nor more, than eight gallons of water to four sacks (one barrel) of coating shall be employed to mix the waterproof coating ready for application.

Walls and Their Preparation.—All walls, such as enclose the general basement, and such as have footings beneath the basement floor, shall first be prepared by chipping off the entire skin of their inner basement surfaces, not more than two days ahead of the coating of them that is to follow. Thoro brushing of the chipped surfaces, with stiff wire brushes, shall next follow, not farther ahead of the coating work than twenty-four hours, to remove every particle of substance

* From Hydrolithic Co.'s specifications.

from the wall that may be loose and infirm. Following close upon the heels of the wire brushing all deep crevices and holes shall be thoroly rinsed and slush coated, as will further be explained, and then filled—large voids with waterproofed concrete (waterproofed coating with clean, crusht rock or gravel), and small voids with waterproofed coating, the outer surfaces of which shall be left rough.

Immediately before the coating work begins, the chipt and wire-broomed walls shall be thoroly rinsed and soakt with clean water. The water is to be impinged with force upon the walls (scrubbing with stiff brooms or scrubbing brushes may be substituted) to insure the removal of every particle of dust, and to thoroly soak, to its full hygrometric capacity, the material of which the walls are constructed.

Following quickly upon the rinsing and soaking of the walls, but not so closely as to subject the freshly applied coating to the oozing of a possibly over-soakt piece of wall, the "slush coating" shall be applied. To prepare this, some of the mixt, ready-for-use coating shall be thinned with water to the consistency of thick cream. It shall be applied with a palmetto, or an equally strong-fibred scrubbing brush, with a scouring effect, care to be exercised to fully cover, in this manner, the inner surfaces of all crevices and holes.

Application of Coating.—Quickly, before the slush coating can show markt signs of drying, the first application of the regularly mixt coating shall be applied ($\frac{1}{4}$ or $\frac{3}{8}$ of an inch thick) directly upon the slush coating, and pressure enough shall be applied to the trowel to push the coating home to the utmost limit of every unevenness, void, or crevice that may by any chance or circumstance exist in the structural surface.

Endeavor must be earnestly exercised by the waterproofer to apply a second and final application of coating ($\frac{1}{4}$ or $\frac{3}{8}$ of an inch thick) before the first applied coating shall have reached its final setting point. Should there be causes at any time to prevent this, then the first application shall be floated with a wooden float before it has reacht the point of its final set, and the surface so floated shall be thoroly scracht or roughened. Then, before the final coating is applied to this scracht portion, its surface shall be thoroly rinsed and slush coated in the same manner as has been described for this treatment of structural surfaces.

The finisht wall coating shall be of a flat, filled out, smoothly troweled surface, free from pits, pin holes, sagging cracks, and all porous imperfections, and be of a full average thickness of $\frac{5}{8}$ of an inch. It shall everywhere be thick enough to float and pack well, without any rolling of the grits in the coating. The floating shall be done at the moment when and while it may thus be packt and densified from top to bottom. Any portion of coating which becomes set before it has been floated shall be entirely removed from the structural surface by chipping, wire brooming, and scouring, and the surface so obtained shall be recoated with freshly mixt waterproofed coating before this portion of the work will be accepted.

The joining of one day's work to a previously applied and hard set coating shall be to straight edges, cut at the time when the older work is being finisht. To make the joining, the edge shall first be scrapt with the edge of a trowel or scraper; slush coating shall then be scrubbed into this edge, and fresh, regularly mixt coating shall be hard rubbed, back and forth, under the nose of a pointer trowel, into the preceding slush coat. This point shall again be well packt when

the floating and the finish troweling takes place. The wall coating shall extend from El. down to El. , coincident with the bottom line of floor, if floor has not been laid; shall join floor coating with a cove or fillet, if floor has been laid and is itself to be coated; shall extend to floor line and out upon the same six inches, with cove or fillet in corner, if floor has been laid and is itself not to be further coated.

Steel Columns Imbedded in Walls.—(a) The granite, brick or concrete footing shall have a 1 in. thick damp course of waterproofed coating laid and bonded to its top surface, and the same shall extend (4 in. if possible) beyond the shoe and structure enveloping the column.

(b) The column shall be imbedded in a concrete envelope, or surrounded by a hard, burnt brick and cement mortar wall; prior to the bilding of the main wall the waterproofed coating shall cover the entire exterior surfaces of the back, sides and front of the envelope, connecting with the damp course beneath the base. After this, the main wall of masonry, or of concrete, shall be bilt between columns by the mason contractor, and the connection between walls and columns shall then be made as shown upon drawings.

Basement Floors.—To withstand hydrostatic pressure, they shall be bilt by the waterproofing contractor, and shall be of such design, thickness, and reinforcement as shown on plans. They shall be so thoroly constructed as to bear an unconditional three-year bonded guarantee to withstand a hydrostatic head of feet.

The aggregate of this concrete shall be:

1st. Of four parts of washt, clean gravel that carries no sediment or clay, and which shall, for 60% of its bulk, be of sizes that shall range from 1½ in. to 1 in., and, for 40% of its bulk, shall range from 1 in. to and including ¼ in. A strong, hard, crusht trap rock may be substituted for gravel, but lime stone should only be selected when neither gravel nor trap is obtainable.

2d. Of three parts of clean, strong, and hard Torpedo sand that carries no silt, clay, calcareous, micaceous, carboniferous, or vegetable substance. The grains of this sand shall, for 50% of the bulk, pass a No. 6 foundry screen and rest upon a No. 14 screen; for the other 50% of the bulk, the grains that pass the No. 14 screen shall rest upon a No. 40 screen.

3d. Of one part of a high-grade Portland cement, tested, for permanency of form, setting qualities, and tensile strength, 90% of which shall pass a 200 mesh screen. The mixing of these aggregates shall be, if by machine, in a batch mixer, and water shall be added sufficient to cause an elongated ball, when moulded and comprest in the hands, to hang together for a space of three seconds, if held suspended at one of its ends.

Hand mixing shall not be done unless performed on the following plan, and the architect may at any time order it stopt, and machine mixing substituted therefor, should he be of the opinion that the method of hand mixing is not being strictly observed and carried out as specified:

1st. The sand and cement shall be mixt together dry, without the gravel, and turned over and over until all parts of it shall have been thoroly commingled, as will be indicated when the color of the mix is the same thruout the entire mass.

2d. The gravel shall be spread upon the mixing platform in a parallelogram

of even thickness. It shall then be thoroly drencht with water until it is wet thru and thru.

3d. The dry mixture of sand and cement shall be spread evenly over the surface of the parallelogram of wet gravel.

4th. The whole mass of gravel, sand, and cement shall be shoveled, over and over, end upon end and side upon side, completely, three times, light sprinkling of water being given the while, with care being exercised to produce an exact and even dampening of the mass.

Twenty-four hours after the concrete shall have been laid its surface shall be prepared to receive the coating in the manner as has been specified for a preparation of walls, excepting that wire brushing or brooming will answer in the place of chipping, save only on patches where the tamping brings neat cement to the surface and leaves it to become a hard, smooth glaze. Such patches shall be chipt until every vestige of the glaze is removed. The rest of the procedure for coating the floor shall be exactly as described and specified for wall coating, excepting that the workmen who will be engaged in cleaning, slush coating, and plastering the floor surface shall not pass to a cleaned and prepared-for-coating space without first carefully cleaning and rinsing the soles and heels of their shoes.

This contractor shall provide and install a system of underdrainage beneath the floors, amply capable, at all times during construction, of accommodating the flow of water to one or more pump sumps in such a manner as to positively preclude any possibility of a rise of water into the concrete during the construction and waterproofing of the floor. The sump, or sumps, shall be of manufacture, so constructed as to be capable of a tight seal at the close of operations, and yet such as may be opened at will, at any future time. These shall be set in the concrete of the floor and in connection with the underdrainage, in the manner as shown in the detail drawings for this feature in the floor construction.

The waterproofing shall be a 1 in. thickness of coating, applied as a wearing surface to the concrete base of the floor, not earlier than twenty-four hours nor later than forty-eight hours after the concrete shall have been laid and tampt in place.

Testing for Soundness.—When all coating, both on wall and floor, has become hard and firm (three to five days being allowed therefor), it shall then be tapt or sounded by the architect or his superintendent, a light hammer being used, and any hollow or shelly places thus revealed shall be entirely cut out with sharp steel points and recoated. The bond of the coating to floor or wall shall at every point of contact be firm and sound.

Machinery Foundations and Anchors.—Where such foundations are to be within or beneath a basement floor, they shall be a monolithic part of the same, and all anchor bolts shall be set in waterproofed sockets, and these shall be set in the concrete at the time it is placed in position. Templates for the proper positioning of such sockets will be supplied.

Treatment of Interior Columns.—Such as will have their bases below the finisht, waterprooft surface of the floor shall have their granit, brick or concrete footings topt with a damp course of a 1 in. thick waterproofed coating, extending beyond the metal vases, or shoes, of columns at least two and if possible six inches. The

floor construction around such columns shall form a wall, or pit, whose depth shall coincide with the thickness of the floor, the latter overlapping four inches the damp course that will have been laid on top of the footings of the columns in question. The floor waterproofing shall extend from the top surface of the floor over the sides of the pit, connecting with the damp course on the top of the footings, which latter will constitute the floor of the pit.

The pits about the column bases shall be closed by slabs of concrete or metal covers, the top surfaces of which shall coincide with the general surface level of the floor. They shall be capable of removal at will.

Treatment of Girders Entering Outside Walls Below Water Level.—The top of the wall, whereupon such girders will rest, shall be coated with a thickness of three inches of waterproofed coating, extending three inches beyond the edges, ends and sides, of the beam. After the beam, or girder, shall have geen placed in position, that part of the member which will overlap the wall must be wholly envelopt in a uniform, 3-in. thickness of coating, ends, sides, and top, this envelope to be bonded, as described for joints on walls, to the 3-in. base of waterproofed coating.

Treatment of Pipes and Conduits Piercing Floors or Walls Below Water Level.—Steam and hot water pipes, or any pipes at all that will be subjest to considerably varying temperatures, and therefore to consequential degrees of expansion and contraction, shall be provided with waterproofed expansion accommodators, to be set, if possible, at the time of placing the concrete, whether for floor or wall.

All other pipes or fittings piercing either floor or wall must be sandblasted, emeried, or otherwise made bright, with every vestige of paint, grease, or other foreign substances removed from their contact surfaces, and be set in the concrete structure with waterproofed coating. This should be done at the time of placing the concrete in position, but may be done afterwards, when holes may have to be cut thru the concrete for the purpose.

Guarantees.—All work shall bear a three-year bonded guarantee, absolute and unconditional, if the supporting structure be bilt by the waterproofer, but modified by and limited to indisputable settlement, weakness or instability, if the supporting structure is constructed by other than the waterproofer.

Old, Completed Structures, Whose Waterproofing is Faulty or Which for Other Causes Need Waterproofing.—Generally speaking the specifications for old bildings, tunnels, etc., or those completed without waterproofing, are about what would be necessary for new work, but there are a few conditions which require special handling.

Treatment of Interior Columns with Bases Below the Surface.—The columns are either to be temporarily removed for a bilding up of their footings above the floor level, with the waterproofing of the bilt up structure in continuity with that of the floor coating, or else they must be encased with an envelope of waterproofed concrete, based on the floor and rising to a level above that of high water.

Treatment of Columns Partially Encased in Outer Walls.—The investing material must be cut away from the column at least three inches back toward the outer surface of the wall, and the under surface of the floor, and that part of the columns thus denuded must be cleaned to brightness; the brightened surfaces of the metal and the surfaces of the cut-away parts, must be scoured with slush coating, and the cuts filled with the ordinary mixture of coating. This in turn must connect with the coating upon walls and floor.

COMPOSITION OF SOME OF THE WATERPROOFING COMPOUNDS IN USE.

In the "Sylvester process" a hot solution of soap, prepared by dissolving ¾ lb. of Castile soap in 1 gallon of water, is first brusht over and into the surface of the concrete, and allowed to dry for twenty-four hours. At the end of that period a second wash, consisting of 2 oz. of alum dissolved in 1 gallon of water, is applied in the same manner. The alum solution should be at a temperature of from 60° to 70° Fahr. The double operation is to be repeated as often as necessary or desirable, but four such coats are said to be impervious to a head of 45 ft. of water.

In "Handbook for Superintendents of Construction, etc.," the following cement wash is recommended for making a water-tight lining for cisterns: A stock solution is prepared of 1 lb. "lye," 5 lb. alum dissolved in 2 quarts of water One pint of this solution is stirred into a pail of water containing 10 lb. of cement, and the mixture is applied to the surface of the concrete with a brush.

Another method is to apply a rendering composed as follows:

1. Portland cement 1 part, sand 1 part.
2. Portland cement 1 part, sand 2 parts, lime paste ½ part.
3. Portland cement 1 part, sand 3 parts, lime paste 1 part.
4. Portland cement 1 part, sand 5 parts, lime paste 1½ parts.

The surface of the rendering, composed according to one of the above formulæ, is brusht with a solution of 1 lb. "concentrated lye," 5 lb. alum, and 2 gallons water, in the proportion of 1 pint of this solution to 5 lb. of cement.

In principle the above-named methods are alike, and all depend upon the precipitation within the surface pores of the concrete, or outer coat, of insoluble alum soap, or hydrate of alumina, or both together. The last-named example, however, combines to some extent the method of pore-filling in bulk with sand and lime paste.

In "Plastering, Plain and Decorative," Miller recommends painting the surface of the work with a hot mixture prepared by mixing 20 lb. of chopt suet with 1 bushel of lime, and stirring up with boiling water.

Professor Hatt states that with a mortar composed of 1 part of cement to 2½ parts of bituminous ash, when alum and soap were mixt with the water used for gaging, the strength and hardness increast 50 per cent. and absorption decreast by the same amount. One-half of the water used for gaging was a 5 per cent. solution of ground alum, and the other half was a 7 per cent. solution of soap. The alum solution was used first.

Cunningham proceeds on similar lines. He uses powdered alum equal to 1 per cent. of the combined weight of sand and cement. To the water used in the mix he adds 1 per cent. of yellow soap.

Hawley employed a stock solution of 2 lb. caustic potash, 5 lb. powdered alum, and 10 quarts water. A finishing coat was made with 3 quarts of this solution in each batch of mortar containing 2 bags of cement. The mortar was made with 2 volumes of sand to 1 of cement, and the work covered to a depth of ½ in.

Marsh gives the following as a waterproof coat or rendering: 2 lb. soft soap, 12 lb. alum, 30 gallons water per cu. yd. of the mortar. Or, 2 lb. caustic potash, 5 lb. alum, 10 quarts water. Of this solution 3⅔ quarts are used for 2 bags of cement and twice its volume of sand.

It will be observed that these processes again depend upon the precipitation of aluminium soap or of hydrated oxide of aluminium, the only difference being that, in these cases, the precipitate is mixt with the mortar instead of being deposited at the surface of the hardened material.

Gaines, in a paper recently publisht, states that watertight concrete can be made (1) by replacing the mixing water with a dilute solution of a suitable "electrolyte" (*i.e.*, a 1 per cent. or 2 per cent. solution of alum); (2) by replacing 5 per cent. to 10 per cent. of the cement with dried and finely ground colloidal clay; (3) by combining methods (1) and (2). With regard to the second of these processes, the action appears to be simply one of pore-filling with fine particles of clay, inasmuch as no "electrolyte" is used; and in the other cases it is probable that the same kind of action takes place by precipitation of alumina, from the "electrolytic" solution, by calcium hydroxide, whether the electrolytic theory itself be correct or not.

It may be remarkt that the use of pulverized clay for this purpose is old.

"Lux," Patent No. 4606 of 1904. This material is prepared by pouring over 100 kilos of cement clinker (unground) 10 litres of boiling water containing 245 grams of stearine, 12 grams of potash (presumably caustic potash, altho it is not clearly stated), and 10 grams of colophony (*i. e.*, common resin).

Gallagher's Waterproof Compound.—This material is to be added to cement in the proportion of 2 per cent. to 5 per cent. on the weight of dry cement before mixing with the sand and water. Its composition has been stated to be chiefly lime and magnesia, with about 3 per cent. of stearine or other fatty acid.

		Per cent.
	Free fat (tallow or stearine)	20.22
Lime soap	Combined fatty anhydrides	14.55
	Combined lime	1.57
	Lime	30.45
	Magnesia	21.15
	Hygroscopic water	3.32
	Combined water	5.77
	Silica	1.17
	Alumina and ferric oxide	1.18
	Sulfuric anhydride, etc	.62
		100.00

Cold bituminous dampproof paints, such as Horn's Dehydratine, Toch's R. I. W., Antihydrine, etc., for use on the interior surfaces of exposed walls or for exterior of foundations not subject to water-pressure. These are made up of specially selected asphalts dissolved in carbon bisulfide or some kindred hydrocarbon, the proportions varying according to the use to which same is to be put.

Paraffin, or other mineral substance, dissolved in gasolene with the addition of resin as a hardening agent, proportions varying according to use. This is employed for surface application to walls, etc., that are to be rendered watertight. Trade names: Dehydratine, Waxol, Anhydrol, etc.

Hydratite, Medusa, Maumee, Whitehall, Toxement, etc., and similar powders in very finely divided state. These are metallic stearates to which are added varying proportions of hydrated lime, alum, and clay. Two per cent. of the compound is usually added to 1 bag of cement before the addition of water.

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Paper No. 1062.

PYROMETERS FOR MEASUREMENT OF HIGH TEMPERATURE.

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(Junior Member.)

Read at meeting of Junior Section, Oct. 12, 1908.

The great importance of accurate means of determining the higher temperatures is now generally recognized, and where fifty years ago it was sufficient to determine and regulate temperature by gaging with the eye the variations in the color of heated substances, at the present day pyrometers are considered a necessity in laboratories and in modern industrial works.

The necessity of having a heat-measuring instrument which can be relied upon as accurate has led many men to investigate the subject in recent years, particularly in the steel industry, not only in the blast furnaces, but also in the hardening, tempering, and annealing of the steel, where it has been necessary to gage accurately heats within 20 degrees, or thousands of dollars worth of steel would be ruined. The writer knows of an instance at a well-known steel works where the customers in ordering several thousand dollars' worth of steel specified the temperature at which they desired it annealed. On receipt of the steel by the customers it was found that it had not been annealed, as they thought, at the proper temperature. The manufacturers of the steel, however, produced records from several recording pyrometers, dated and certified to as being an accurate record of annealing temperatures of that particular quantity of steel, and it saved the manufacturers several thousand dollars in that one instance to be able to prove their case.

In the manufacture of glass, for instance, not only the temperature in the glass-melting furnaces must be regulated to prevent the color being burnt out of the glass by excessive heat, but also the accurate annealing of the glassware is most important. After the glass has been blown and molded, it must be transferred immediately to an annealing lehr, in which, if the temperature is accurately regulated, the bottle will be so annealed that it will not crack readily in shipment or in han-

dling. The loss through breakage in the shipping of glassware is severe, and the writer knows of an instance in which the breakage loss has been reduced from 5 to 1 per cent. by the use of pyrometers in the annealing. The superintendent of a works stated to me that their outfit of pyrometers was paid for in one day by the saving in loss from breakage alone.

This condition is not true of the glass and steel works alone, but we might also cite the brick and clay industry, in which the temperature of the kilns must be accurately measured in the burning of their ware, a slight variation in the temperature at the finish of the burn being frequently sufficient to ruin the ware in one-half of the kiln, valued oftentimes at thousands of dollars. It is no wonder, then, that great attention has been paid to this subject recently, and that the Bureau of Standards at Washington has endeavored to assist the manufacturers of pyrometers in producing uniform indications for all of their instruments.

About a hundred and twenty-five years ago, Wedgwood, the celebrated potter of Staffordshire, England, undertook to make a pyrometer which would assist him in gaging the temperature in his kilns for baking or, technically speaking, burning his fine china and earthenware. He succeeded in making an instrument based on the contraction of clay, which was of considerable assistance to him, and for probably fifty years was the only pyrometer known. To the writer's knowledge, this Wedgwood pyrometer is no longer in use, and has probably long been forgotten. Many years ago, also, attempts were made to gage heat by the different melting-points of metals; and by placing a number of test pieces of metal in a furnace, the time of the melting of each metal was observed. At best, this was a very meager guide, as the melting-points of most of the common metals are far apart, and only very expensive metals, such as silver, gold, platinum, etc., could be used at very high temperatures.

About 1886 Dr. Seger, director of the research laboratory at the Royal Pottery Works of Berlin, made a whole set of fusible cones of vitreous clay, containing an excess of several acids. By slightly varying the substance, Dr. Seger was able to make these cones so that they would soften or fuse at intervals of about 25 degrees all the way from 600° to 1800° Centigrade or 1100° to 3500° Fahr. The points of these cones drop over when the fusing-point is reached. Seger cones are very largely used among the brick and clay manufacturers of this country. Strictly speaking, these cones are not a pyrometer, as their

fusing-point is affected very largely by both time and heat. A cone burning fifty hours in a brick kiln will take 50 degrees or more heat to bring it down or fuse it, than a cone in a test kiln heated up in several hours.

About thirty years ago the manufacture of pyrometers based on the difference in expansion of two metals, or in the expansion of one metal and non-expansion of another, was introduced.

Gauntlett, in England, manufactured a pyrometer based on the greater expansion of brass than iron. The expansion pyrometer has been very greatly improved in recent years, and many unsatisfactory points in connection with the original instruments have been done away with. Fig. 1 shows a pyrometer the working of which is dependent on the expansion of a steel stem, and the almost non-expansion of graphite. At the lower end of the steel tube, which is closed by being plugged, are short graphite rods extending for 12 inches. Above these graphite rods is a special tube connected to the indicating movement. Springs tend to pull on the movement, and cause the pointer to move around the dial as the steel tube expands, proportionate to the heat of the furnace or metal bath, the temperature of which is being measured. The 12 inches of graphite at the end of the steel stem must, of course, be all in the heat, as the indicated expansion or temperature would be reduced almost one-half if only 6 inches of the stem was inserted in the heat. The special steel tube above the graphite rods is constructed of various metals by means of which the pyrometer is compensated, so that depths of immersion of the steel stem over 12 inches do not affect the accuracy of the indication. As will be readily understood, this instrument primarily indicated expansion, but by testing the pyrometer in heat with standards, a scale can be graduated to read in degrees of temperature.

Fig. 1.

There are other forms of expansion pyrometer, such as the quick-acting platinum pyrometer illustrated in Fig. 2. This pyrometer differs from the instrument just described in that a thin platinum strip is hung between heavy iron frames at the end of the stem. When the stem is inserted in the heat, the thin platinum strip instantly expands, and reaches the total heat of the furnace, and is fully expanded for that degree of heat within a very few seconds. The heavy iron frame, meanwhile, expands very slowly, and by the time the platinum strip has reached, say, 2500° Fahrenheit, the iron frame has only risen to

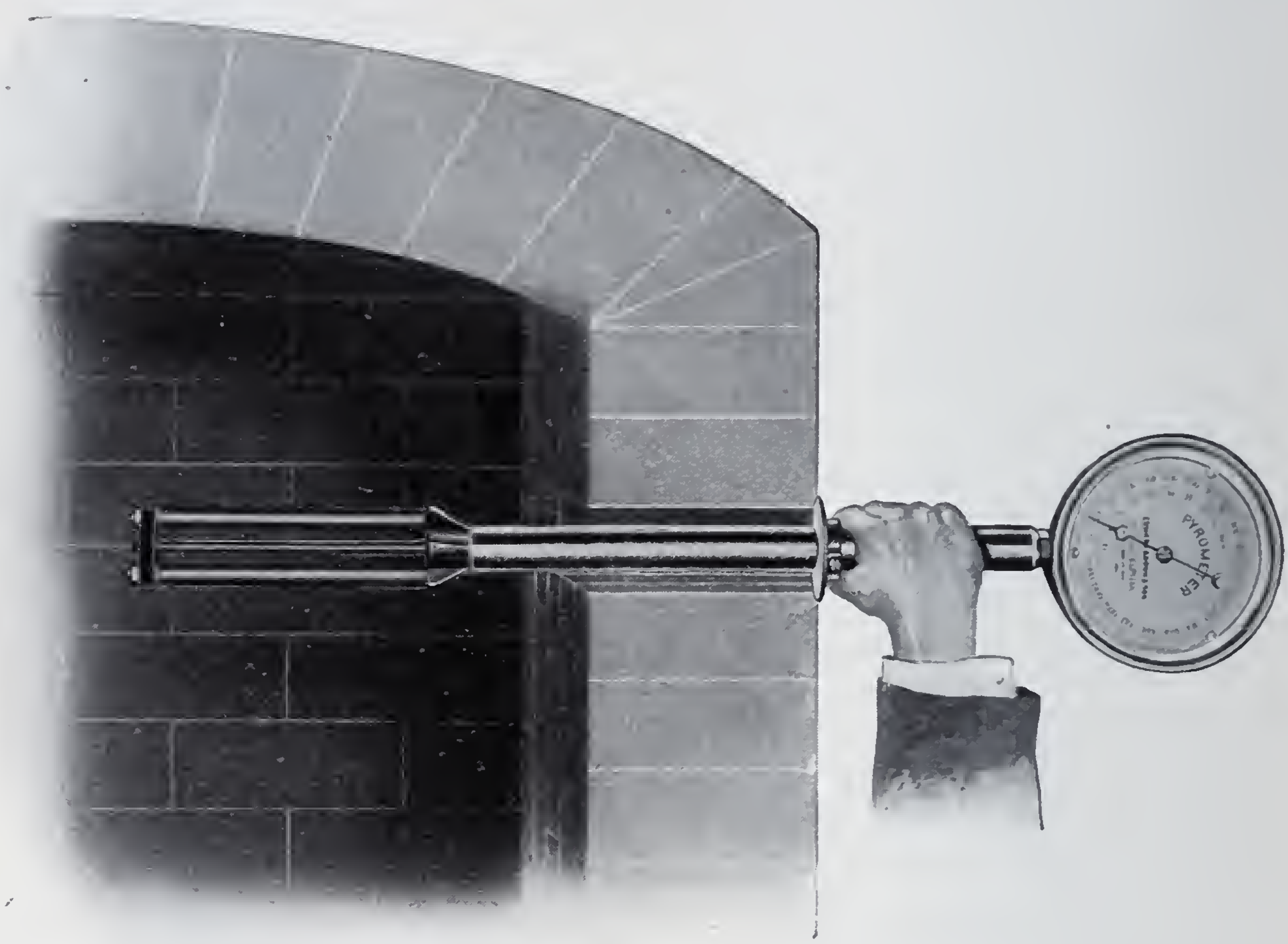

Fig. 2.

several hundred degrees. The instrument indicates the difference in expansion of the heated platinum strip and the slightly heated iron frame, and is calibrated by being tested in comparison with a standard instrument. The portable pyrometer shown in Fig. 3 is used only for blast furnace temperatures and works on the expansion principle, the nozle of the pyrometer being held to the tuyere of a blast furnace, and the hot blast in passing through under about 15 pounds pressure causes a thin strip of metal inside to expand, and this expansion is transmitted to the multiplying movement through a lever and link.

Before leaving the subject of expansion instruments, I should mention the mercurial thermometer. Every one is very familiar with the common thermometer, for temperatures up to several hundred degrees. A thermometer can be constructed for temperatures up to 1000° F. by filling the tube above the mercury with hydrogen gas under a pressure of 25 atmospheres. A thermometer of this form, if carefully made,

Fig. 3

can be relied upon as reasonably accurate, although the instrument is not suited for rough industrial use, on account of its glass construction.

The testing of these pyrometers in comparison with a standardized pyrometer has been mentioned. The recognized standard is the scale of the gas pyrometer. Unfortunately, the gas pyrometer cannot be readily constructed, and it has taken years to construct such an in-

strument. Certain fixed points of fusion and ebullition of metals have been determined by the aid of the gas thermometer. For instance, the melting-points of gold, silver, lead, nickel, tin, etc. The National Physical Laboratory in Germany has for a number of years tested

FIG. 4.

pyrometers in Germany for manufacturers, giving exact tables of correction for reading any instrument sent them. The National Bureau of Standards at Washington, established a few years ago, very ably performs the same service in this country now, and manufacturers

are furnished with accurate standards by which they can test their pyrometers.

Two portable or hand pyrometers, which have been quite largely used in the past twenty years, are shown in Figs. 4 and 5. The Siemens water pyrometer is practically a calorimeter, a small copper cylinder being heated in the furnace, the temperature of which is being measured, and when it has attained the temperature of the furnace, in, say, fifteen minutes, it is quickly withdrawn, and dropped into a

Fig. 5.

specified quantity of water—20 ounces. The copper cylinder naturally raises the temperature of the water, the temperature being indicated on a fine thermometer inserted in the water. The rise in the temperature of the water can be read off on a brass scale, which you will note can be set to the level of the mercury in the thermometer before the water is heated. Temperatures can be read off on this scale with a copper cylinder to 1800° F., and with nickel and platinum cylinders to higher temperatures. These cylinders in time scale away,

and as soon as they become light, must be renewed, or the indication is affected. This pyrometer is considered by many firms to be very satisfactory, and it is used largely by the Bethlehem Steel Company in annealing and in a number of blast furnace plants for hot blast temperatures.

The Hobson hot blast pyrometer (Fig. 5), used only for the temperature of the hot blast at furnaces, chiefly in England and our southern States, is constructed as follows: The nozle is held to the tuyere at a blast furnace, and three parts of cold air are drawn in at this opening, while one part is drawn in of the heated air. The temperature of the mixture is indicated on a thermometer, which has a brass scale placed alongside it, on which actual temperature of the hot blast can be read off. This pyrometer is approximately accurate, but its indication is materially affected by the pressure of the blast on the furnace, which may range from 10 to 25 pounds.

We now come to a type of pyrometer most generally used in this country and abroad, known as the electric pyrometer. Le Chatelier was the first scientist to work out in a systematic manner the thermoelectric pyrometer, and an instrument based on his discoveries has been very largely used during the past ten years, known as the Le Chatelier pyrometer. The essential feature of this pyrometer is a junction of two metals, which, when heated, generates a small electromotive force, dependent only on the temperature to which the junction is heated, at least under certain conditions. Le Chatelier chose one metal or wire of chemically pure platinum, and the other of platinum 10 per cent. rhodium, both of which have a melting-point above 3000° F., and when the two wires are joined at the end, and this junction is heated, about 20 millvolts are generated for a temperature of 3000° F. The two wires, joined at one end, form what is known as a thermocouple. This thermo-couple, usually about three feet long, must be long enough so that the ends of the wires not joined, known as the cold junction, will be at about ordinary room temperature, 75° F. The indication of the electric pyrometer is appreciably affected by changes of temperature of this cold junction, and a rise of 10° at this junction will reduce the indication of the instrument 5°, and vice versâ. The more recent instruments of the Le Chatelier type have had the instrument calibrated for the cold junction temperature of 75° F., room temperature, but many of the early instruments were calibrated for the cold junction at the temperature of melted ice, 32°, and this necessitated immersing the wires of the cold junction in melted ice while the pyrometer was in use.

The thermo-couple wires must be protected from touching each other, which is usually done by carrying one or both of the wires in small porcelain or firebrick tubes or in asbestos tubing. An outside protecting tube of porcelain steel or quartz is used for protecting the thermo-couple against the deteriorating action of the gases of a furnace and to prevent damage to the thermo-couples.

Le Chatelier came to the conclusion that for indicating the small current generated by the thermo-couple a galvanometer was necessary, of very high resistance, to overcome slight changes in the resistance of the platinum-rhodium thermo-couple at varying temperatures, and also of the leads or wires connecting the galvanometer and thermo-couple. A high-resistance galvanometer is necessarily a rather delicate instrument, and until a very recent date it was necessary to manufacture this instrument with the coil and pointer suspended by a fine wire, and such an instrument must be handled carefully. The resistance of the galvanometer varies from 200 to 300 ohms, according to the type and the manufacturer. All galvanometers of the suspension type have to be carefully leveled before a reading is taken, and the instrument must be placed on a very firm foundation or table, which will not be subjected to vibration. The very slightest vibration, such as caused by an engine in an adjoining building, will cause the pointer to vibrate, and prevent an accurate reading. When care is taken to locate the instrument properly and to get it properly leveled, and if it is used in conjunction with a thermo-couple having one wire of chemically pure platinum, the other 90 per cent. platinum 10 per cent. rhodium, we have the most accurate pyrometer at present in use for laboratories or industrial works. The Le Chatelier type of pyrometer is rather more expensive than most other pyrometers, which is due largely to the cost of the platinum thermo-couple. Recently a galvanometer has been constructed by an English concern which has the coil and pointer on jeweled bearings, doing away with the suspension wire and the necessity of leveling the instrument. This galvanometer has, however, only a resistance of about 100 ohms, but its construction is much more suitable for industrial use.

In the past two or three years attempts have been made by a number of manufacturers to construct a thermo-couple of alloys of nickel and steel, in order to do away with the great expense of using a platinum and rhodium thermo-couple, and, at the same time, to be able to supply one which will remain constant in its indication and durable under severe usage. This has been largely accomplished recently by using a thermo-

couple of heavy wire, one wire being nickel and the other various grades of steel. Naturally, one of the main features is to secure wires of high melting-point, and for this purpose one wire of the thermo-couple is of pure nickel and the other of nickel chrome steel. For use with these thermo-couples a milli-voltmeter is being largely used, like the well-known switchboard and portable type of electric measuring instrument (Fig. 6). By using an instrument of this kind, instead of the high-resistance galvanometer, a much less delicate instrument is secured, and one which can be supplied at a very moderate price. This milli-voltmeter is of comparatively low resistance, about five ohms

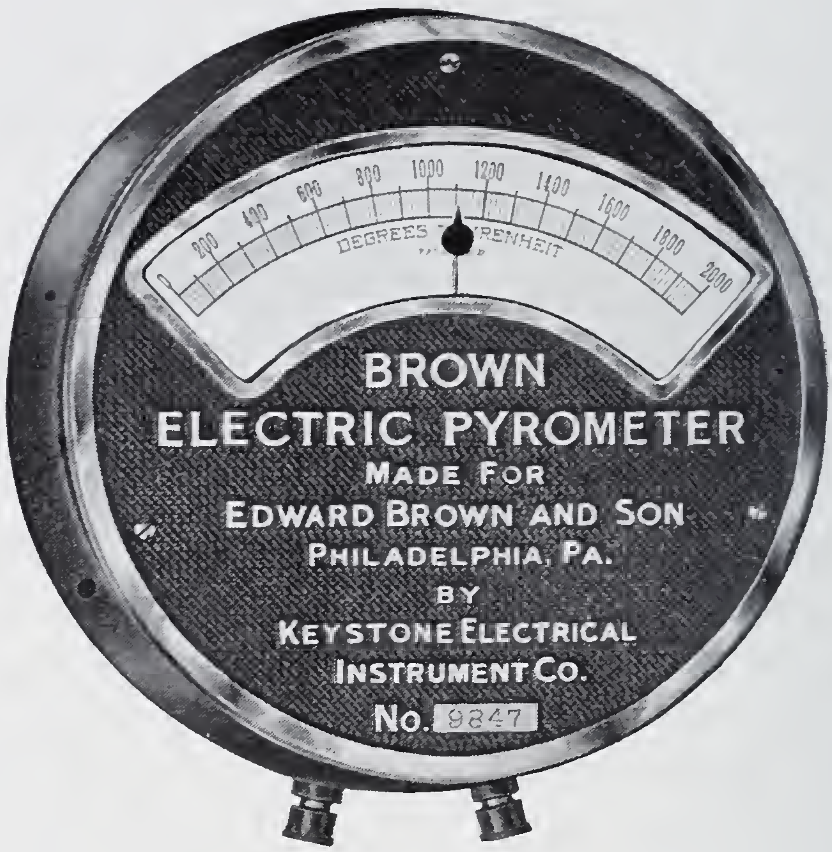

Fig. 6.

being most commonly found. The thermo-couple has to be constructed of heavy wire or rod, to overcome changes of resistance which would be appreciable with the low-resistance instrument. This, of course, can be readily done with wires of nickel and steel, where it would be impossible with the thermo-couple of platinum-rhodium wire, on account of the expense of these metals.

In using the instrument, the size of the wires or leads connecting the thermo-couple and the indicator in this low-resistance instrument is important, and each instrument is calibrated by the manufacturers before shipment, for the specified length of leads and also diameter of wire. Where care is taken with these details, a pyrometer is pro-

duced which is most accurate for temperatures in ordinary industrial use, and one which can be readily installed by the user. Practically, the only repair cost of such an instrument will be an occasional renewal of the thermo-couple or its protecting tube, which is a very small item.

As it is very frequently desirable to keep a continuous record of the temperature on a sheet or chart, a recording pyrometer, or rather a recording milli-voltmeter, is desirable. As the milli-voltmeter is such a delicate instrument, it is impossible to have the pointer press on

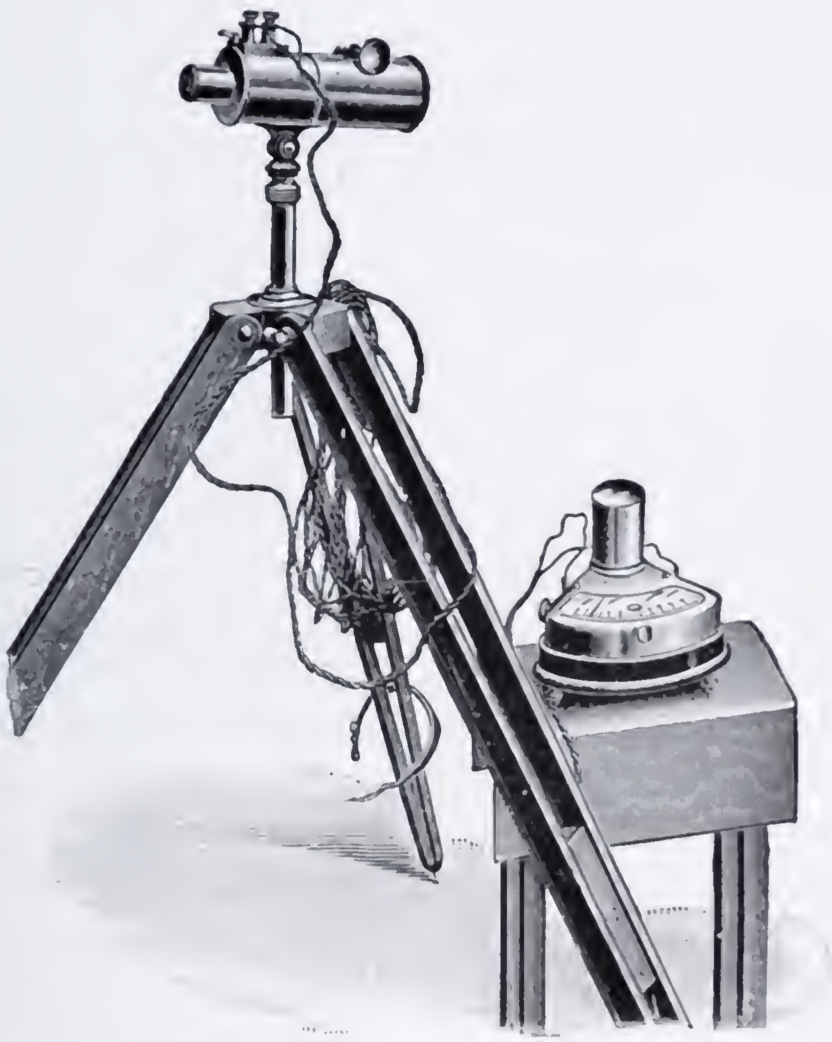

Fig. 7.

the paper sheet constantly. It is customary, in a recording instrument, to cause the pointer to press against the paper once a minute or once every half minute. A record can be made by causing the pointer to carry a small quantity of ink, to depress the pointer or typewriter ribbon, to cause the paper to chemically change color when pressed by the metallic pointer, or, as in the Bristol instrument, the chart is coated with smoke, which is scratched off by the pointer, the record being set by a solution after the chart is removed from the instrument.

Before leaving this subject, mention should be made of pyrometers

suitable for measuring temperatures above the melting-point of platinum. This has been done in several ways, by making use of the laws of radiation, and by comparing a given temperature to a regulated light of flame. The Fery radiation pyrometer (Fig. 7), which is the best-known radiation pyrometer made, has been used for measuring the very highest temperatures, such as the measurement of the temperature of a thermit mold, which was found to be 2500° Centigrade, or 4532° F., and also the temperature of the sun has been found, 7800° Centigrade, equal to 14,072° F., determined by Prof. Fery.

In all pyrometers other than radiation and optical instruments, there is some part, the sensitive or receptive part, which is made to attain a temperature identical with the temperature to be measured. In the measurement of furnace temperatures, for example, optical and radiation pyrometers are the only instruments entirely outside of the furnace. With the radiation pyrometer, invented by M. Fery, Professor of Physics at the School of Mines, France, the instrument is placed entirely outside of the furnace, and no part of the pyrometer is raised above the air temperature more than 80° Centigrade, or 176° F. In this pyrometer the radiation which emanates from a hot body, or which passes out through an observation hole in the wall of a furnace, falls upon a concave mirror and is thus brought to a focus. In this focus is a thermo-electric couple, whose temperature is raised by the radiation falling upon it; the hotter the furnace, the greater the rise of temperature of the couple. Since the energy radiated from a hot body increases very rapidly as the temperature is raised, it follows that the Fery pyrometer is far more sensitive at high than at low temperature. Temperatures as low as 600° Centigrade or 1100° F. can be read, but the instrument is more suitable for high temperature work.

Among other instruments of this type should be mentioned the Mesure and Nouel pyrometer telescope, in which the rotation of the plane of polarization of light passing through a quartz plate, cut perpendicular to its axis, is used to measure temperatures. This can hardly be considered an instrument of precision, although it is serviceable for the approximate control of temperatures about 800° C. (1470° F.), and answers the requirements of many furnace operations sufficiently well. Its great advantage in practical use is that it is encumbered by no accessories whatever.

There is also the Wanner pyrometer and the Morse thermo-gage, in both of which there is a standard flame or light which can be heated to any degree of incandescence, and a means is provided for reading the

degree of incandescence, which has been compared to the heat of the furnace measured. In the Morse gage the substance whose temperature is to be read is viewed through a tube; the incandescent standard, which is located within a tube, is then superposed over the substance being measured, and the lamp appears to be of the same temperature.

This probably covers all types of the pyrometers which are used, or have been used industrially in this country. Each particular type has its advantages under certain conditions, and it is impossible to state that any particular pyrometer is better than another. Without doubt experiments will continue to be made to invent and improve instruments for the accurate measurement of heat, and each advancement and improvement will be a step forward in the systematizing now being attempted in modern up-to-date works.

DISCUSSION OF PAPER No. 1057, "SAND—ITS USES," etc., by W. S. REED* (Read May 16, 1908).

P. A. Maignen.—The paper is so good and so complete that there is very little that can be added to it. The paper alludes to an epidemic of cholera in Paris, and states that "the men who worked on the sewage disposal farm did not suffer from cholera." Now, it so happens that I had the good fortune of helping to stop this Paris cholera epidemic. It is probably quite true that the men who worked on the sewage farm did not suffer from cholera, but those who lived lower down the river and drank water contaminated with sewage did suffer very much.

It was in the early part of 1892 that cholera appeared first in the village of Mazagran, on the outskirts of Argenteuil (near Paris), among a population of men who worked in a gypsum (plaster-of-Paris) quarry. The sole supply of water for the village was drawn from a unique hydrant delivering plain Seine river-water. The men fell sick and died like flies. Shortly afterward the disease broke out in epidemic form in the town of Argenteuil proper, which was supplied with the same water. There were in a few months upward of 800 cases of cholera, with 121 deaths, as also 29 deaths from typhoid fever (the township did not contain at that time more than 5000 or 6000 inhabitants).

At the end of July the Mayor of Argenteuil called on the speaker and requested him to install a public filtering fountain in the village of Mazagran. This was done a few days later—August 8th—and the raw water was shut off. Immediately afterward the disease disappeared from the village entirely. Then the Mayor ordered two more filtering fountains, which were installed in the town of Argenteuil, August 22d and 26th. Another public filtering fountain was purchased and paid for by the Argenteuil Professional Mens' Association, and installed September 3d. The epidemic soon stopped; the few deaths which occurred afterward were old cases. From this time on Argenteuil was practically free from cholera and typhoid, which diseases went on raging for two more years in the surrounding districts using the plain river-water.

The following is the record of deaths from cholera and typhoid fever in the city of Argenteuil from June to October, 1892:

* Printed in Proceedings, vol. xxv, No. 3.

	Cholera.	Typhoid Fever.
June	16	1
July	20	8
August	19	14
September	5	6
October	1	0

The Mayor of Argenteuil wrote to the speaker, one year after the installation of the fountains, as follows:

"It is with pleasure that I state that the filtering apparatus which you have placed at Argenteuil during the cholera epidemic, which raged here last year, have worked in a perfect manner, and we must think that this purification of the water has contributed for the greatest part to remove the causes of cholera and typhoid maladies, which to-day have ceased to exist."

"Ville D' Argenteuil
(Seine-et-Oise) Argenteuil, le 8 Septembre, 1893.

"Monsieur Maignen: C'est avec plaisir que j'atteste que les Appareils de Filtrage de votre systême, placés a Argenteuil pendant l' epidemie cholérique qui a sevi ici, l'année derniere, ont fonctionné d'une manière parfaite et qu'on doit penser que cette purification de l'eau a contribué pour la plus grande part a faire disparaitre les causes des maladies choleriques et typhiques qui, aujourd'hui, n'existent plus.

"Agreez, monsieur, etc.

"Pour le Maire absent
"L'Adjoint
"Chuffar."

I am glad that this subject has been brought forward, because it shows once more that it is the pollution of the drinking-water, and not of the air or of the ground, which does the damage.

You have heard me speak before on the subject of bacteria which are said to coat the grains of sand, to lie in wait and deliver a death-blow to the new-coming bacteria. The author gives us an echo of this doctrine, which is known as the "biological" doctrine, and which I once called a "romance." Bacteria do not eat one another so far as we know—they are caught in the sand as mice are caught in a trap, and they die in the mud. Their dead bodies, with small pieces of vegetable matter or algæ, and with particles of clay and dirt, combine together to fill the voids between the grains of sand, and thus render the filter finer or closer, until it is so fine that the water ceases to pass through.

The accumulation of sediment on the top of the sand, so often called "mud blanket," is held by those most experienced to be a very delicate membrane. It is easily broken by the air escaping from the body of the sand, by worms, eels, etc., and by the more or less unequal settlement of the sand in the filter-bed. Evidence has been accumulating

lately abroad and in this country tending to show more and more that this "mud blanket" is not absolutely necessary for a good filtration, while it may be very disappointing to those who trust in it too much. Much better results can be assured by preparing the water for filtration by some preliminary treatment and by taking care that the sand used is the best that can be had for the purpose. If there is one thing that has struck me more forcibly than another in the selection of sand by different engineers during the last few years, it is that economy rather than quality has been sought. I approve of economies in accessories, but not in that which does the work.

When a sand filter is new or freshly resanded, the filtered water outlet is partially closed, so as to check the rate of filtration; otherwise the water would pass much too rapidly. It is well known that at the beginning of the operation the filtered water is not good. This may be due to the unsatisfactory method of sand-cleaning or to the fact that the sand layer is not sufficiently packed or settled down.

The methods of washing filter sand now in use are most unsatisfactory. We know of a plant in which the sand was considered sufficiently well washed when the wash water contained still as much as 4000 parts per million of turbidity. At other plants 400 parts have been allowed. I would not consider a sand properly washed that would give a wash-water with more than 40 parts per million.

Any system of washing sand which produces stratification or separation of the fine grains from the coarse is to be deprecated. After a few washings the sand is so coarse that it cannot do its work properly.

The method of judging the size of filter sand by what has been termed "effective size" and "uniformity coefficient" has been devised by well-informed experts, but it must be acknowledged that it is "Greek" to many of us. It may be very scientific, but it is "arbitrary," and it might be well to suggest something simpler for the convenience of ordinary men, such as sand dealers, contractors, and filter superintendents. Why not, for instance, say this: "A good sand for slow filtration is that which passes through a sieve with 10 to 14 meshes to the linear inch, and is retained on a 60- or 80-mesh sieve, with fairly equal proportions of the different sizes between." A sand which is graded to one or two uniform sizes must necessarily be very expensive, and it is not fit for slow sand filtration. If used for mechanical filters, it will certainly let the water go through at a very high rate, but the filtration cannot be effective unless the water has been thoroughly coagulated; any failure in this respect makes the filter itself a "delusion and a snare."

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 19, 1908.—The meeting was called to order by the President at 8.15 p. m., with 90 members and visitors in attendance.

The Secretary presented a communication from the International Congress of Refrigerating Industries, to be held in Paris, France, from October 5 to 10, 1908, giving a list of the American members and the program of the Congress.

The death of Mr. Howard Bain, Junior Member, which occurred on August 31, 1908, was announced.

Announcement was made of the classes in building construction to be held by the Central Y. M. C. A. beginning October 1, 1908.

Owing to the amendment to Article 1, Section 8, of the By-Laws, not having been printed in the notice of the meeting, the matter did not come up officially before the Club, but was discussed informally by Wm. Easby, Jr., who spoke on the desirability of increasing the membership before any action had been taken toward placing a limit on same.

The nominations of the Board of Directors for membership in the Nominating Committee for the year 1908 were, upon motion, approved. The Nominating Committee will, therefore, consist of Messrs. Silas G. Comfort, E. M. Nichols, Edwin F. Smith, J. C. Parker, and Harrison W. Latta.

Mr. W. P. Dallett stated to the Club that the Board had secured Mr. Charles S. Redding, Junior Member, as Manager of the Club-house, and bespoke the coöperation of the members with his work.

Mr. A. B. Stitzer, Active Member, presented the paper of the evening, "Calibrated Speed Recorder," which was discussed by Messrs. Wm. Easby, Jr., Richard P. Brown, L. H. Rittenhouse, Charles Hewitt, E. B. Smith, and the author.

The meeting adjourned at 9.15 p. m.

Business Meeting, October 3, 1908.—The meeting was called to order by Vice-President William Easby, Jr., at 8.20 p. m., with 100 members and visitors present. The minutes of the business meeting of September 19th were approved as printed in abstract.

The Secretary made an announcement regarding the starting of the proposed Company of Engineers, and stated that Capt. Dunning, of Company A, First Battalion of Engineers, would be at the Club-house on Tuesday, the 6th, with some of the members of his Company.

The proposed amendment of the By-Laws, Article I, Section 8, was discussed.

The Secretary read the following resolutions by the Board of Directors at the meeting held October 3d:

Resolved, That the members of the Board of Directors are unanimously in favor of the proposed amendment to the By-Laws, Article I, Section 8, limiting the members of the Club, and recommend the passage of the same by the Club.

Mr. L. F. Rondinella proposed an amendment to the amendment, making it read as follows:

Article I, Section 8.—The total number of members of all grades, at any one time, is not to exceed 760, of whom not more than 10 may be Honorary Members, and not more than 75 may be Junior Members.

The amendment was discussed by Messrs. Fairchild, Hess, Quimby, and Rondinella.

The amendment as above given was accepted by a vote of the Club and ordered to letter ballot.

The Secretary read extracts from Mr. Myron H. Lewis's paper, "Waterproofing—An Engineering Problem."

The paper was discussed by Messrs. DeKnight, Richard L. Humphrey, E. Shriber, Henry H. Quimby, William Easby, Jr., and H. G. Perring.

The meeting adjourned at 10.20 p. m.

Business Meeting, October 17, 1908.—The meeting was called to order by the President at 8.25 p. m., with 120 members and visitors in attendance. The minutes of the meeting of October 3d were approved, as printed in the abstract.

Secretary announced the death of William S. Vaux, active member, which occurred July 23, 1908.

Secretary announced that Friday, the 23d instant, had been set as the night on which final action would be taken in the matter of forming Company B, First Battalion of Engineers, N. G. P.

Report of the Tellers was read, showing that Frank H. Burns, Robert Sanford Riley, Charles Philip Bauer, and Charles W. G. King had been elected to Active Membership; Thomas Haines Griest, John Horridge, E. Haldeman Finney, and Henry Brussell Bryans had been elected to Junior Membership, and Walter K. Mitchell to Associate Membership; that the Amendment of the By-Laws, Article I, Section 8, limiting the membership of the Club, had been carried, there being 84 ballots for, and 17 against, 67 votes being necessary to approve.

Mr. John C. Parker, active member, presented the paper of the evening, on "The Development of Down-Flow Boilers," which was discussed by P. A. Maignen, E. B. Carter, Arthur C. Jackson, Mr. Fennell, and the President.

The meeting adjourned at 10 p. m.

Business Meeting, November 7, 1908.—The meeting was called to order by the President at 8.20 p. m., with 125 members and visitors in attendance. The minutes of the meeting of October 17th were approved, as printed.

Amendments to the By-Laws were presented, as follows:

Article I, Section 7, change to read "Honorary and Junior Members shall not be entitled to vote or to hold office, but shall enjoy all other Club privileges. Associate members shall enjoy all the privileges of Active Members, except that they cannot hold the office of President or Vice-President."

Proposed by H. P. Cochrane, Geo. T. Gwilliam, H. G. Perring, W. P. Dallett, Henry H. Quimby, Wm. C. L. Eglin, S. M. Swaab, W. B. Reigner, R. G. Develin, Jas. C. Wobensmith, Jos. A. Wolle, H. F. Sanville, and John E. Allen.

Article IV, Section 6, change the first section to read: "The Board of Directors shall consist of the President, Vice-Presidents, Secretary, Treasurer, and Directors. In the absence of the President and Vice-Presidents, the financial

duties of the President shall be performed by a President pro tem., elected by the Board of Directors."

Proposed by W. P. Dallett, H. P. Cochrane, Wm. Easby, Jr., J. O. Clarke, S. M. Swaab, Jos. A. Wolle, H. F. Sanville, Jas. C. Wobensmith, and John E. Allen.

Article V, Section 5, strike out the last sentence, which reads: "The number of Honorary Members shall not exceed ten at any one time."

This provision is now included in the new Section 8 of Article 1, together with the numerical limitation of total and Junior membership.

Proposed by L. F. Rondinella, W. F. Ballinger, Edwin S. Hutchinson.

Article VI, Section 2. Replace "of Resident Junior Members, $10," by "of Resident Junior Members, $12.50, of which $2.50 shall be set apart for the use of the Junior Section, payable on its order."

A new Article to be placed before the present Article X:

JUNIOR SECTION.

(1) All the Junior members shall constitute the Junior Section.

(2) The Junior Section shall be governed by such By-Laws as it may adopt, not conflicting with the Charter or By-Laws of the Club.

Proposed by W. P. Dallett, Henry H. Quimby, and Wm. Easby, Jr.

In accordance with the By-Laws these Amendments were ordered held over until the Business Meeting of December 5th.

Mr. Harrison W. Latta, active member, presented a paper on "The Foundations for the Building for the United States Naval Experiment Station at Annapolis, Md.," which was discussed by Messrs. E. G. Perrot, C. Chester Wilson, and W. F. Ballinger.

Mr. F. G. Myhlertz, active member, presented a paper, "Should Engineers, Architects, and Builders Be Licensed?" which was discussed by Messrs. A. H. Lehman, D. K. Boyd, F. M. Harris, Jr., H. G. Perring, E. G. Perrot, S. M. Swaab, E. M. Nichols, W. F. Ballinger, W. L. Webb, Manton E. Hibbs, L. F. Rondinella, Edward S. Hutchinson, and Dr. H. W. Spangler.

The meeting adjourned at 10.20 P. M.

BUSINESS MEETING, November 23, 1908. The meeting was called to order by the President at 8.15 P. M., with 133 members and visitors in attendance The minutes of the last meeting were approved as printed in abstract.

The Nominating Committee reported as follows:

For President (to serve one year), W. P. Dallett.

For Vice-President (to serve three years), Philip L. Spalding.

For Secretary (to serve one year), W. Purves Taylor.

For Treasurer (to serve one year), H. E. Ehlers.

For Directors (to serve three years), George T. Gwilliam, Charles F. Mebus Edward S. Hutchinson, A. C. Wood.

Respectfully,

S. G. COMFORT,
EDWIN F. SMITH,
E. M. NICHOLS,
JOHN C. PARKER,
HARRISON W. LATTA.

Report of the Tellers was read, showing that George Washington Hyde William Eckley Dodds, James Robert Buchanan, and William Henry Johnson, Jr., were elected to Active Membership; that Louis Christian Smith, Stehman Atlee Bockius, Stanley Hubert Wright, and John Andrew Baumgardner were elected to Junior Membership, and that Joseph Van Eman Titus, George Andrew Bauer, and Richard W. Yerkes were elected to Associate Membership.

The Secretary read a communication from Thomas Kolischer, representative of the Club to the First National Congress of Refrigerating Industries at Paris, France, relative to his attendance at that Congress.

The President referred to the proposed organization, in the Club, of a Company of Engineers, to be connected with the National Guard of Pennsylvania, and urged the members to give it serious consideration, that the organization might be perfected at an early date.

Mr. F. G. Myhlertz presented a resolution, which, in accordance with the By-Laws, will come up for discussion at the next business meeting of the Club. The resolution is as follows:

"That a committee of three be appointed, empowered to confer with similar committees from other organizations, and to codify matters relating to the subject of endeavoring to secure the passage of a law requiring that all who practise the professions and occupation of Engineer, Architect, or Builder shall be licensed."

Mr. C. D. Ehret, Active Member, presented the paper of the evening, "Wireless Telegraphy and Telephony," which was discussed by Messrs. H. C. Snook, E. G. Perrot, Edgar Marburg, Carl Hering, Henry Hess, Oscar C. Schmidt, F. L. Miller, and Thomas G. Janvier.

The meeting adjourned at 10.30 P. M.

BUSINESS MEETING, December 5, 1908.—The meeting was called to order by the President at 8.25 P. M., with 144 members and visitors in attendance. The minutes of the meeting of November 23d were approved as printed in abstract.

The several proposed amendments to the By-Laws, which had been presented at the meeting of November 7th, in accordance with the By-Laws, were presented to the Club for discussion.

Amendment to Article I, Section 7: change to read: "Honorary and Junior Members shall not be entitled to vote or to hold office, but shall enjoy all other Club privileges. Associate Members shall enjoy all the privileges of Active Members, except that they cannot hold the office of President or Vice-President." This amendment was discussed by Prof. Lino F. Rondinella and Mr. Edward S. Hutchinson, who spoke against it, and showed that, in some places, it conflicted with the By-Laws; and by Mr. W. P. Dallett and the President, who spoke in favor of the proposed amendment. Ordered to letter ballot in this form.

The proposed amendment to Article IV, Section 6: change to read: "The Board of Directors shall consist of the President, Vice-President, Secretary, Treasurer, and Directors. In the absence of the President and Vice-Presidents, the financial duties of the President shall be performed by a President pro tem. elected by the Board of Directors." After the President had pointed out that the second sentence of the proposed amendment was but a repetition of another sentence in the By-Laws, the proposed amendment was changed to read as follows: "The Board of Directors shall consist of the eighteen officers of the Club." Ordered to letter ballot in this form.

The proposed amendment to Article V, Section 5: Strike out the last sentence of Section 6, which reads, "The number of Honorary Members shall not exceed ten at any one time." This amendment was explained by Prof. Lino F. Rondinella. Ordered to letter ballot.

The proposed amendment to Article VI, Section 2: Replace "of Resident Junior Members, \$10.00," by "of Resident Junior Members, \$12.50, of which \$2.50 shall be set apart for the use of the Junior Section, payable on its order." This was explained by Mr. E. J. Dauner, President of the Junior Section. Mr. Dauner explained that it was necessary to secure more money to defray expenses of the Junior Section. Ordered to letter ballot.

The proposed new Article in the By-Laws, to be placed before the present Article X:

JUNIOR SECTION.

1. All the Junior Members shall constitute the Junior Section.
2. The Junior Section shall be governed by such By-Laws as it may adopt not conflicting with the Charter or By-Laws of the Club.

This was discussed by Prof. Lino F. Rondinella, who proposed an amendment to Section 2 of the new article, to read as follows: "The Junior Section shall be governed by such By-Laws as it may adopt, with the approval of the Board of Directors." Ordered to letter ballot in this form.

Mr. F. G. Myhlertz presented the following resolution, which, according to the announcement of this meeting, was to be offered for discussion:

"That a committee of three be appointed, empowered to confer with similar committees from other organizations, and to codify matters relating to the subject of endeavoring to secure the passage of a law requiring that all who practise the professions and occupation of Engineer, Architect, or Builder shall be licensed."

This resolution was discussed by Messrs. F. G. Myhlertz, A. E. Lehman (letter), John C. Trautwine, Jr., and the Secretary. The resolution was adopted by vote of the Club.

In accordance with Article V, Section 11, of the By-Laws, opportunity was afforded the members to make additional nominations for the officers of the Club for the ensuing year.

Mr. Michael Monaghan, Junior Member, presented the paper of the evening, "Engineering Features of the Athletics' Baseball Park." The paper was illustrated by lantern slides, and was discussed by Messrs. H. P. Cochrane, T. Jamison Solomon Swaab, Walter Loring Webb, and the Secretary.

The meeting adjourned at 10.20 P. M.

BUSINESS MEETING, December 19, 1908.—The meeting was called to order by the President at 8.30 P. M., with 170 members and visitors in attendance. The minutes of the meeting of December 5th were approved as printed in abstract.

The Secretary read the report of the Committee appointed to "consider the advisability of holding a reception to which ladies are to be invited, for the purpose of seeing the Club-house." The Committee reported in favor of the project, and stated that the subcommittees had been appointed.

The list of members transferred by the Board of Directors from one grade to another was read, as follows:

From Junior to Active Grade:

Henry L. Benner, Carl P. Birkinbine, John A. Boers, J. S. Bradford, L. S Bruner, H. K. Bunting, W. H. Butler, Jr., St. G. H. Cooke, Charles H. Dading E. J. Dauner, F. H. Gilpin, William H. Gravell, John Gwilliam, James F. Haldeman, R. A. Harrower, J. S. Haug, W. Y. Heaton, Joseph M. Herr, E. Hoopes, Y. M. Karekin, H. T. McGaughan, Michael Monaghan, William D. Polk, Charles S. Redding, J. I. Rogers, Jr., Samuel Sinclair, E. I. Snyder, H. E. Snyder, S. B. Strouse, A. W. Way.

From Associate to Active Grade: H. Clyde Snook.

From Junior to Associate Grade: J. G. Hendrie.

Mr. A. M. Loudenslager presented the following resolution, which was seconded by Mr. George T. Gwilliam, and, in accordance with the By-Laws, laid over until the next business meeting of the Club:

"*Resolved*, That the Board of Directors be authorized to design and adopt a suitable badge for the membership of the Engineers' Club."

The Secretary announced that the box placed on the Bulletin Board for contributions to the employees' Christmas fund had been placed by authority of the Board of Directors.

Mr. G. Edward Smith was nominated for the office of Secretary of the Club by the following members: John C. Trautwine, Jr., John C. Trautwine, 3d, Edward S. Hutchinson, Richard Gilpin, Henry J. Hartley, Ernest G. Turner, Lino F. Rondinella, Charles F. Schaeffer, James D. Faires, and William H. Hansell.

The Tellers of election reported, showing that 157 legal ballots had been cast, and that William Wallace Atterbury, Edward Johnson Baechle, Albert Herman Miller, and Edwin A. Moore were elected to Active Membership; that Francis Curtis Hubley was elected to Junior Membership, and that J. Russell Hibbs was elected to Associate Membership.

The Tellers also reported the following as the result of the balloting on amendments to the By-Laws:

Amendment to Article I, Section 7, not carried, there being 89 votes cast in favor of the amendment and 48 votes cast against it, 91 votes being necessary for approval.

Amendment to Article IV, Section 6, was carried, there being 112 votes for and 25 votes against, 91 votes being necessary for approval.

Amendment to Article V, Section 5, was carried, there being 114 votes for and 21 votes against, 90 votes being necessary for approval.

Amendment to Article VI, Section 2, was carried, there being 124 votes for and 11 against, 90 votes being necessary for approval.

The addition of a new Article X was carried, there being 128 votes for and 7 against, 90 votes being necessary for approval.

Mr. Paul W. England, Active Member, presented the paper of the evening, "Underground Conduit." The paper was illustrated by lantern slides, and was discussed by Messrs. Carl Hering, Clayton W. Pike, William C. Eglin, Edward Cunningham, James Heywood, and S. M. Swaab.

The meeting adjourned at 10.30 P. M.

ABSTRACT OF MINUTES, BOARD OF DIRECTORS.

Special Meeting, September, 11, 1908.—The meeting was called to order by the President at 8 P. M., with Vice-Presidents Dallett and Easby and Directors Clarke, Christie, Perrot, Hess, Twining, Cochrane, Dodge, and the Secretary and Treasurer in attendance. The minutes of the regular meeting of June 24, 1908, were read and approved.

The President announced that he had communicated with Mr. William C Williamson and had persuaded him to withdraw his resignation as a member.

A letter from Mr. C. W. Todd was read. The Todd Company propose to take over the responsibility of the Club bookkeeping by placing one of their men in the Club to keep the books. They will also audit the Club accounts and submit to the Board of Directors such reports, trial balances, etc., as are required. This they propose to do for the sum of $22.50 per week. Mr. Gwilliam suggested that both the night and day clerk be put under this audit company. Upon motion, the whole matter was referred to the Chairman of the Finance Committee and the Treasurer, with power to act.

The Chairman of the Finance Committee presented a statement as to the Club finances, which showed that there was a deficit in the Club's monthly accounts. The matter was discussed, and in the course of discussion it was suggested that as a means of economy it might be well to employ a manager for the Club-house, who would have full authority over all employees, etc., but no definite action was taken.

Upon motion the President was authorized to have the periodicals on the second floor placed in the back reception room on the first floor; and have the billiard table set up. Upon motion, the President was authorized to fit up book-shelves in the library.

The Secretary was instructed to put a note in the next notice concerning the relation between the Engineers' Club and the Library of the University of Pennsylvania.

The Membership Committee reported three applications.

The meeting adjourned at 9.45 P. M.

Special Meeting, September 16, 1908.—The meeting was called to order by the President at 8.15 P. M., with Vice-Presidents Dallett and Devereux and Directors Quimby, Twining, Clarke, Dodge, Cochrane, and the Secretary and Treasurer in attendance.

The President announced that he had called a meeting to take definite action in regard to engaging a manager for the Club. After some discussion, upon motion, the whole matter was referred to a committee consisting of the Chairman of the House Committee, Chairman of the Finance Committee, and the Secretary, with power to act.

A letter from Mr. Geo. B. Hicks, Secretary of the Founders' Week Executive Committee, was read. Mr. Hicks asked that the Club consider the matter of entertaining distinguished guests of the city at the Club-house during Founders' Week, and the Secretary was instructed to reply courteously that all the rooms in the house would be in use by the members.

The meeting adjourned at 9.15 P. M.

REGULAR MEETING, September 19, 1908.—The meeting was called to order by the President at 5 P. M., with Vice-President Dallett and Directors Perrot, Cochrane, Develin, Twining, Clarke, Dodge, and Ledoux, and the Secretary and Treasurer in attendance. The minutes of the special meetings of September 11th and 16th were read and approved.

The resignations of George P. Connard and Robley A. Warner were read and the Secretary was instructed to communicate with these gentlemen and endeavor to persuade them to retain their membership.

The special meeting to consider the matter of placing the treasurer's office under an outside auditing firm reported that they had favorably considered the matter and tentatively accepted the proposition of Mr. C. W. Todd; that a contract was being drawn up and would probably be signed during the coming week.

The President reported that the matter of setting up the billiard table and removing the periodicals to the back reception room had been attended to, and that the shelves for the library would shortly be in place.

The question of the change in the telephone service of the house was discussed and the matter left with the House Committee for report to the Board.

The special committee to consider the advisability of securing a house manager reported that they had considered the matter favorably, and had secured Mr. Charles S. Redding, Junior Member, as manager of the Club. The following general regulations as to the Manager's duties were read:

The Manager is an officer of the Board and not an employee of the house. His duties shall be:

1. The general superintendence of the employees of the house.
2. The recommendation to the Board, through the House Committee, of any changes in methods or in the duties of employees which will result in increased efficiency or reduced expense.
3. The hiring and discharging of all house employees under conditions determined by the proper officers of the Club, and he is to see that they are properly employed at all times while in the house.
4. The fixing of hours of labor and seeing that they are rigidly adhered to, and the changing of such regulations as he finds necessary.
5. The signing of all requisitions for supplies, etc., for the house, and he is to be responsible for the proper receipt and use of all house supplies.
6. Keep order in the Club-house. See that the employees do not enter or use any portion of the Club-house or Club property that their duties do not require.
7. Have entire charge of the clerical work in the Secretary's office, open mail, and see that all work is properly done and at the right time.
8. He will have charge of the office work connected with the Committees on Publication, Library, and Membership, and see that intelligent service is rendered by the clerks.
9. He will have entire charge of the restaurant under the House Committee. All changes of servants will be made on his order and every attempt must be made to keep the expense to a minimum.
10. The Steward's duties shall be confined to the providing and serving of meals and keeping that portion of the house in order. He will hereafter have no control over other house employees.
11. The Manager will take direct charge of all other employees, keep their number to a minimum for efficient service, and see that they perform such duties as he may prescribe.

12. All portions of the Club-house will be under his direct supervision and must be kept in proper order.

13. He will assign to the clerks such duties in connection with the periodicals and library as will render these of most service to the members.

14. He will issue such orders as he sees fit to insure the attendance of all employees of the Club in the Club-house while on duty, and will cause the clock record to be properly kept.

15. The Manager's duties do not require his presence at the meetings of the Club, nor of the Board, unless he is directed to appear.

16. Room 39 is assigned to the Manager for his occupancy. Proper meals, of the same character as those supplied other Club members, will be served him, and the cost of them will be charged by the bookkeeper to house wages, etc.

17. Any other service that he may desire will be charged as to any member. There are to be no other perquisites.

18. The Manager is to be paid $100 per month at the end of each month.

The meeting adjourned at 5.45 P. M.

Special Meeting, September 26, 1908.—The meeting was called to order by the President at 8.15 P. M., with Messrs. Dallett, Easby, Christie, Twining, Dodge, Ledoux, Hess, Head, Perrot, Clarke, Cochrane, Develin, and the Treasurer present. Mr. Quimby telephoned and asked to be excused.

The President read a letter that he had sent to Henry S. Black & Son in reference to the restaurant, and the reply thereto. After discussing the advisability of having the restaurant handled by an outside caterer, Mr. Hess moved "that the Board approves of running the restaurant by the House Committee at a loss of two hundred dollars per month with the expectation of getting the loss down to that amount or less within a reasonable time." The motion was seconded by Mr. Christie, who offered an amendment reducing the amount of the loss to one hundred dollars, which was accepted by Mr. Hess. When the question was put, the motion as amended was lost. Mr. Hess then moved "that, in lieu of the present system, the House Committee contract with a caterer to carry on the restaurant at no loss." Mr. Develin offered an amendment to insert "at the best possible terms, to be confirmed by the Board," instead of "no loss." The amendment was not accepted by Mr. Hess, but was carried by the Board; and the amended resolution was also carried.

After discussing the indiscriminate use of the telephones by the house employees, and others, on motion of Mr. Dodge, the President was authorized to have the telephone contracts changed and to substitute two pay telephones if possible for each of the present Bell and Keystone telephones.

The President read a note from Mr. Redding, the Manager, in reference to the junk in room 43. On motion of Mr. Christie the matter of displacing the junk was referred to the House Committee, with power.

There was some discussion as to the best way of securing the payment of dues from members in arrears; and in connection with this matter it was thought advisable to have a complete list of members posted at the doorway, so that the members entitled to the privileges of the Club could be known and those in the Club-house marked by pegs.

The President brought up the matter of the offer of the firm of accountants to provide a bookkeeper, which he had not accepted because of the uncertainty as to the disposition of the restaurant, and asked for the opinion of the Board as

to the continuance of the restaurant. The opinion being that the restaurant should be continued, he stated that the offer would be accepted immediately.

On motion the meeting adjourned at 10.20 P. M.

Special Meeting, October 3, 1908.—The meeting was called to order by the President at 5.15 P. M. with Vice-Presidents W. P. Dallett, Washington Devereux, and Wm. Easby, Jr., Directors Twining, Develin, Christie, Hess, Cochrane, Clarke, and Quimby, and the Secretary in attendance.

The President stated that the meeting had been called together with the hope that the House Committee had a definite report to make with regard to the restaurant. The House Committee reported that they had no definite report to make, but that they had advertised for a caterer to conduct the restaurant and had gotten but little result from this advertisement. Negotiations were under way with Black & Son with the view of having this concern conduct the restaurant, and an early decision is expected.

The President announced that a contract had been entered into with C. W. Todd & Company to look after the books of the Club, and this company had taken charge of the books on October 1st. The bookkeeper employed by the Club had been given a week's notice that his services would no longer be required.

The President announced that a contract had been entered into with the Bell Telephone Company for a pay station 'phone on the first floor, for which we were to pay $1.50 per month, and the separate service in the fourth floor office at $66.00 per year.

The Keystone Telephone Company had not replied to communications addressed to them.

The President stated that he had received a letter from Mr. Clay, of John Wanamaker, with reference to our account at that store, which is now past due, and he suggested that some one who had had dealings with Mr. Clay attempt to adjust the matter on the basis of deferred payments. Upon motion, Mr. W. P. Dallett was authorized to attempt to make settlement. The suggested basis of settlement being $500 in cash and notes for $500, payable in two, four, and six months.

The Chairman of the House Committee stated that for the past few weeks the rooms of the house had been practically full and the financial returns therefrom were encouraging.

The proposed amendment of the By-Laws limiting the membership of the Club was discussed, and the following resolution passed:

Resolved, That the members of the Board of Directors are unanimously in favor of the proposed Amendment to the By-Laws, Article 1, Section 8, limiting the members of the Club, and recommend the passage of the same by the Club.

Mr. James Christie suggested the advisability of disposing of the Club bonds now held by the Treasurer.

The meeting adjourned at 6.30 P. M.

Regular Meeting October 17, 1908.—The meeting was called to order by the President at 4 P. M., with Vice-President W. P. Dallett and Directors J. O. Clarke, Henry H. Quimby, H. P. Cochrane, J. P. Loomis, James Christie, Henry Hess, and the Secretary and Treasurer in attendance.

The minutes of the special meetings of September 19th and 26th and October 3d were read and approved.

The President presented a statement, showing the financial operation of the restaurant under the management of Black & Son for the first week, which showed a saving to the Club over the old management.

The President called attention to the large increase in current consumption of the lighting of the house.

The President brought up the matter of pro rating the dues of members elected during the second half of the year, and, upon motion of Mr. Clarke, it was resolved that at the request, in writing, of the Membership Committee, the dues of members admitted during the last half of this year be remitted for the months of the half year preceding the month in which they were elected.

The President called attention to the large number of delinquent accounts on the books of the Club, and suggested that steps be taken at once to force members to settle these accounts.

The following resolution was presented by Mr. Hess:

That House Rule No. 12 is too drastic, and that the following be substituted: "If a member is delinquent twice in six months, he shall be posted. Bills shall be rendered on the first of the month for the entire preceding month's indebtedness. If a bill is unpaid within thirty days of the date it is rendered, it is to be considered delinquent. The credit of a member whose bill remains unpaid fifteen days after the date of the bill, shall cease."

This motion was not seconded.

Mr. J. O. Clarke presented a resolution, amending House Rule No. 12, which was, upon motion, carried. The Rule, as amended, reads as follows:

"All orders for articles served must be signed by the member ordering. All bills are due when incurred, and may be paid at the Treasurer's office, or may be charged and paid at the end of the month upon presentation of the bill. A second bill shall be sent at the end of the following month, and the names of members failing to settle accounts by the 15th of that month shall be posted. The credit of members in arrears shall be stopped fifteen days after the date of the first bill."

Upon motion of Mr. Christie, it was resolved that the House Committee take steps to collect the bills of the delinquent members to date.

Upon motion of Mr. Clarke, it was resolved that the President be authorized to appoint a Committee, outside the Board, to catalogue the library.

The President reported that the Bell Telephone Company had not yet installed a pay station telephone in the Club-house, but they had been notified that, from the date of contract, the Club would pay calls on the basis of pay station prices.

The President stated that the Keystone Telephone Company would not make a change in the telephone installation, and asked permission to order the Keystone telephone taken out. This authority was granted by resolution of the Board.

Upon motion of Mr. Christie, it was resolved that the President and Treasurer be authorized to retire the fifty-dollar bond of Mr. W. H. Hansell, and credit him with the difference between his account with the Club and the value of his bond.

Upon motion of Mr. Christie, it was resolved that the Board authorize the delivery of Club's second mortgage bond, in amount, $2000, to Wm. L. Austin, having received his indemnity bond against duplication.

Mr. E. J. Dauner, President of the Junior Section, was introduced, and asked the Board to consider a change in the By-Laws, raising the dues of resident Juniors to $12.50 per year, $2.50 of this to be turned over to the Treasury of the Junior Section.

Mr. Dauner also made some other suggestions relative to the Junior Section, and was advised to have the necessary amendments put in writing, to be presented at an early business meeting of the Club.

The meeting adjourned at 6.05 P. M.

SPECIAL MEETING, November 7, 1908.—The meeting was called to order by the President at 4.30 P. M., with Vice-Presidents W. P. Dallett and Wm. Easby, Jr., and Directors James Christie, J. W. Ledoux, Henry H. Quimby, H. P. Cochrane, W. S. Twining, Francis Head, and the Secretary in attendance.

The Secretary read communications from W. F. Ballinger, E. G. Perrot, and the Gulf Coast Inland Waterway Association, of Jacksonville, Florida.

The resignation of Frank S. Clarke was presented and accepted.

Mr. Wm. Easby, Jr., presented the result of the deliberations of the Chairman of the Membership Committee and the Chairman of the Finance Committee, on the matter of retirement of second mortgage bonds held by the Link-Belt Company by payment of initiation fees and dues of members designated by that company.

After some discussion the matter was referred to Mr. H. P. Cochrane to take up with Mr. J. M. Dodge, with a view of learning if the proposed disposition met with Mr. Dodge's approval before any final action was taken by the Board.

The President called attention to the large number of delinquent accounts for both dues and restaurant and house charges; and the Secretary was instructed to communicate with all delinquents, and inform them that the provision of the By-Laws, relative to dropping delinquent members, would be enforced, and active legal steps taken to collect their accounts.

Mr. J. W. Allison and Mr. C. W. Edmonds were, upon resolution, dropped from the membership list; and the Board decided not to take any active steps to collect their accounts.

Upon motion of Mr. James Christie, seconded by Mr. Easby, it was resolved that the House Manager immediately turn over to the Treasurer all funds, of any character, relative to the Club, received by him, and take receipt therefor.

The President reported that for twenty days the restaurant had been in the hands of Black & Son. The Club was eighty cents ahead on gross receipts.

The matter of the Club's indebtedness to Ballinger & Perrot, for architectural services in connection with the new Club-house, was brought up, and left in the hands of the President for adjustment.

Mr. E. J. Dauner, President of the Junior Section, was introduced, and presented some proposed amendments to the By-Laws, covering the recognition of the Junior Section therein.

The meeting adjourned at 6.40 P. M.

REGULAR MEETING, November 21, 1908.—The meeting was called to order by the President at 4.30 P. M., with Vice-Presidents Dallett, Easby, and Devereux,

and Directors Cochrane, Christie, Develin, Clark, Hess, Ledoux, and Head, and the Secretary and Treasurer in attendance.

The minutes of the regular meeting of October 17th and the special meeting of November 7th were read and approved.

The President presented a statement, covering the operation of the restaurant, showing a slight increase in cost of operation to the Club for the past month.

The matter of the Membership Committee's qualification of membership in the matter of Mr. H. Clyde Snook was brought up, and, upon motion, was referred back to the Membership Committee, the President referring to Article III, Section 7, of the By-Laws, which states that "The proceedings of the Membership Committee shall be private and confidential, and no member thereof shall be questioned as to its action."

Upon motion of Mr. James Christie, the Secretary was instructed to write to Mr. A. E. Lehman that his check covering dues for the last half of the year 1908 would be placed to his credit as also covering dues to the end of the year 1909. This action was taken in view of Mr. Lehman's ill health not permitting him to enjoy the privileges of membership, although he still desired to retain membership.

In accordance with the resolution passed at the meeting of the Board November 7th, the Secretary communicated with the members who were in arrears in their dues to the Club, and received replies, which were read. Upon separate motion in each case, the following disposition was made:

E. E. Seyfert. Resignation to be accepted after payment of all obligations.

B. H. Tripp. To be rendered bill for one year at $15.00 and one year at $12.50.

C. C. Anderson. Time of payment extended for thirty days.

A. H. Bromley. Time extended for thirty days.

Walter Frick. Resignation accepted as of January 1st.

W. W. Nichols. Time extended for thirty days.

R. N. Sargent. Secretary to advise that he is within the distance set by the By-Laws for Resident Membership, and is responsible to the Club for resident dues.

John V. Rice. Time extended for thirty days.

J. L. E. Cheetham. Proposers to be communicated with, with a view of securing payment.

Thos. W. Jenks. Drop from membership list, and take active steps to collect the account.

C. W. Edmonds, R. C. Heath, F. D. Howell, Jr. Laid over until the first of the year 1909, because of the great distance of residence from Philadelphia.

J. H. Stitzer. Time extended for thirty days.

The resignation of Carroll Phillips Bassett and Harry M. Hillegass were presented and accepted to take effect December 31, 1908.

Mr. J. M. Dodge was introduced, and made a statement relative to the proposed retirement of bonds held by the Link-Belt Company. Upon motion of Mr. Easby it was resolved that the matter of retirement of Club's second mortgage bonds held by the Link-Belt Company, by the payment of initiation fees and dues of such members as were designated by that company, be referred to the Chairman of the Finance Committee and Mr. J. M. Dodge, to make satisfactory arrangements and report to the Club.

A letter from Mr. Theodore Kolischer was read. In this letter he announced his safe return from the First International Congress of Refrigerating Industries

held in Paris, France, at which convention he attended as a delegate from the Engineers' Club of Philadelphia.

The meeting adjourned at 6.15 P. M.

Special Meeting, December 12, 1908.—The meeting was called to order by the President at 4 P. M., with Vice-Presidents W. P. Dallett, Wm. Easby, Jr., and Directors J. O. Clarke, J. W. Ledoux, F. E. Dodge, John Loomis, James Christie, Francis Head, Richard G. Develin, Wm. S. Twining, H. P. Cochrane, and the Secretary and Treasurer in attendance.

The President stated that he had called the Board together to obtain action toward securing the money now held in the various saving accounts and the bond account, in excess of $1500, for general Club use.

It was resolved, upon motion of Mr. Christie, seconded by Mr. Easby, that the proper officers of the Club be authorized to take the necessary steps to transfer the funds held in saving account and in the bond account, in excess of $1500, to the general Club fund.

Mr. Christie reported that satisfactory arrangement had been made with Mr. Jas. M. Dodge, relative to the second mortgage Club bonds held by the Link-Belt Company, and that the bonds were now in possession of the Club.

Upon motion of Mr. Christie, it was resolved that the Link-Belt Company's bonds be handed to the Trustees of the Bond Redemption Fund, to hold, subject to the direction of the Board of Directors, the Trustees to use the coupons for the purposes of the Trust.

Upon motion of Mr. Christie, it was resolved that the proper officers of the Club be authorized to draw up a Certificate to the Link-Belt Company, acknowledging the receipt of the second mortgage bonds of the Club, in amount $1000, and state therein the reasons for holding.

Upon motion of Mr. Christie it was resolved that Messrs. C. W. Todd & Co., the Club's accountants, be instructed to prepare a complete statement of the Club's accounts, for purposes of the annual report, this statement to show assets and liabilities, and income and expense.

The case of Robley A. Warner, Active Member, came up for discussion. Mr. Warner owes the Club $65.00, of which $25.00 is for advertising and $40.00 for dues. It developed that Mr. Warner had ordered the advertisement and had O. K.'d the proof which had been sent to him; but, upon being billed therefor, stated that the advertisement had been taken by mistake, and was, at the time, not said to be an advertisement, but to be the insertion of his name in the Club Directory of members. Upon motion, it was resolved that the Secretary write Mr. Warner, stating that in the event of his further refusal to pay his indebtedness to the Club, the Board of Directors would drop him from the list, and take legal steps to collect the amount.

Upon motion, it was resolved that the President be given permission to furnish the Club with a bulletin board, and the thanks of the Board of Directors be extended him.

The meeting adjourned at 5.05 P. M.